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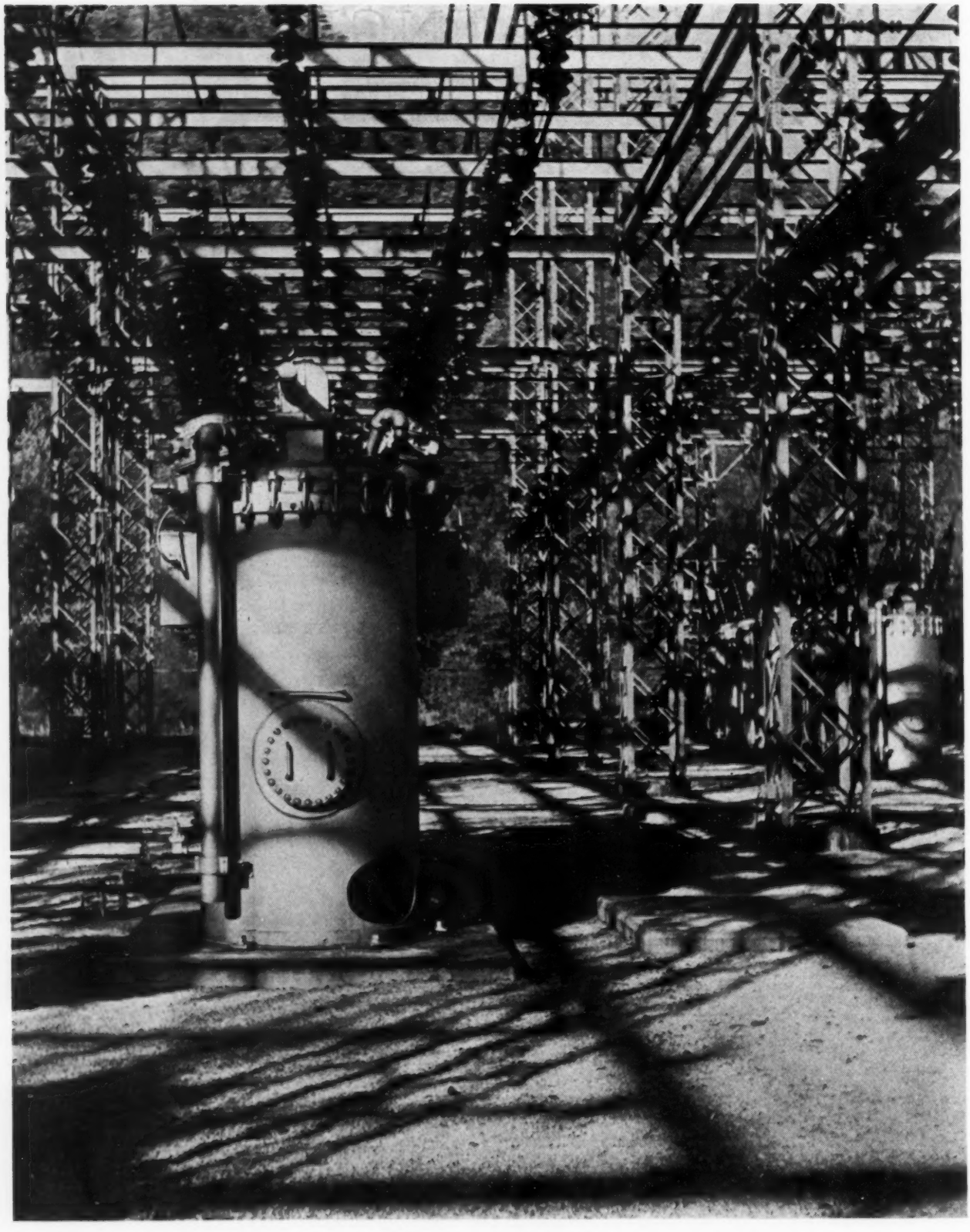

Light and Shadow

(Picture taken by John P. Ferris, Mem. A.S.M.E., at the Waterville, N. C., plant of the Carolina Light & Power Co.)

VOLUME 60
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MECHANICAL ENGINEERING

SEPTEMBER
1938

GEORGE A. STETSON, *Editor*

Tribute and Query

SUMMER is the season for record flights and pioneering in aerial navigation. This year we have witnessed the spectacular round-the-world flight of Howard Hughes and his companions in 3 days and 19 hours, further development of the catapult-launched German planes and the nonstop, Berlin to New York, adventure of the *Brandenburg*, and the record crossing of the *Mercury*, long-distance member of the Mayo composite craft, not to mention the astounding hop of Corrigan, whose homing instincts appeared to be better than his compass. There has been much to talk about and plenty of honors to go around, according to your national, scientific, or emotional interests. Plenty, too, to think about and ponder, with planes in other parts of the world raining death and destruction on helpless inhabitants of unhappy cities, and evidence, wherever one goes in Western Europe, of the dread with which aerial warfare is viewed. Nor should the toll of accidents be completely forgot in the flush of pride over the triumphs of aviation, especially that unexplained and lamentable loss in the Pacific, which cast a shadow on the splendid record of one of this country's most famous air lines. Aviation has had an eventful summer.

It remained for Howard Hughes to break the record where placing credit is concerned, and for radio commentator Boake Carter to pick up the tribute Hughes paid to the men who had made his achievement possible and drive it home to millions of his countrymen who never get beyond the ticker-tape stage of hero worship. Said Hughes of his flight:

"We who did it are entitled to no particular credit . . . . All the real credit is due the test pilots, the draftsmen, the engineers, the mechanics, the clerks, and the field-workers who through all these years have made such flights possible. They get no ovation such as this but they deserve it more than we do. For them the hours of backbreaking work, the disappointments, and the heartaches. And if this flight has given them any satisfaction in realizing their work has been well done, we are happy."

In the radio broadcast of July 15 in which this passage from Hughes' tribute was quoted, Boake Carter went on to elaborate the theme in a manner that engineers can applaud without detracting one bit from the credit that the fliers themselves received and deserve. That numerous company of coworkers whom Hughes lauded must have derived justifiable satisfaction in listening to his gracious mention of their contribution to his success; just as engineers probably thought of the remainder of Boake Carter's broadcast, "Here at last is a publicist who understands what engineers are doing for their fellow men. Perhaps the time will come when we shall hold the public esteem to which we are entitled."

For years engineers have reminded themselves of their value, and, somewhat petulantly at times, have become impatient at the withholding of what appears to them to be a deserved recognition, expressed not only in glowing words but in the more concrete form of preferment in economic status and public opinion. Without in any way condemning these attempts at building up a professional self-consciousness—for it has been our studied policy to indulge in them—the opportunity should not be missed to say once more that the responsibilities of the engineering profession cannot be lightly assumed.

In parallel columns of the *New York Times* for July 25 the editors had something to say about doctors and engineers. Probably there was no intended parallel in the two editorials, yet it is hard to escape reading into them more than was actually written. In one of these editorials the medical profession was taken to task for its attitude toward "the group practice of medicine." The other dealt with the so-called "monopoly investigation" of the Temporary National Economic Committee created by the last Congress and, among other things, raised the following query:

"The chemists, engineers, physicists, and financiers who are in the first instance the organizers and directors [of corporations] have given our culture its present cast. How can the imagination and ingenuity of these men and their corporation employees be given full rein without granting them a power over human destiny greater than that exercised by any government?"

In accepting the tributes of Howard Hughes and Boake Carter we are reminded that we live in a world which may cry "Hail, Caesar!" one day, and "Death to the Tyrant!" the next. We are treated to a tribute and a query.

A Wreath for Watt

ONE OF the happy incidents at the International Engineering Congress at Glasgow in June was the tribute to James Watt which took the form of the laying of a wreath at the base of his statue. Appropriately enough, the ceremony was performed, and the tribute, which represented the engineers of all nations, was

spoken by Dr. Matschoss, former director of the Verein deutscher Ingenieure, distinguished student of the history of technology, with whom the idea of honoring Glasgow's most famous engineer originated.

Earlier the same evening Herr J. Dillgardt, Oberburgermeister of Essen, in responding for the delegates to the Congress to the remarks by the Provost of Glasgow, paid tribute to Scottish engineers who had done much for Germany, and recalled the fact that as early as Queen Elizabeth's reign German engineers had been sent to England to develop its mineral resources.

In such incidents as these the universal character of engineering is illustrated. The fruits of Watt's genius could not have been confined to Great Britain, and the importation into England of German mining technique was but one of millions of examples of the resistless diffusions of knowledge and skill, to say nothing of blood, that have been going on since the world began.

The stronger passions of men as they relate to tribe, to nation, to creed, and to tradition, are not aroused by such cultural penetration as engineering developments initiate. Advantages to living standards deriving from these peaceful interchanges of knowledge and experience may, at times, appear to be overshadowed by threats to security when technology is made to serve the ends of national aggression or when they disturb the internal economy of a community, as frequently is the case. But the world and its inhabitants find progress to have been made in the long run, even though the price of change is a new and confusing set of problems to be solved.

Thus it is worth while to pause occasionally to pay tribute to a great genius or to recall even the lesser debts that one people owes another. The honoring of the military leaders is a familiar and popular function. Engineers could do much to add luster to the prestige of their profession and to remind the world of the debt it owes to men like Watt if they more frequently followed Dr. Matschoss' brilliant example.

Some Thoughts on Standards

EARLY in the summer the American Standards Association issued an eight-page bulletin, copies of which are available on request, which describes its work and is entitled "Standards, What They Are Doing for Industry." The bulletin explains why a national standardizing body is necessary, how standards are made, what benefits accrue to industry through the mechanical standards and safety codes developed by the A.S.A., how they bring about cooperation between industry and governmental bodies, and how they affect foreign trade. It describes also the administrative setup of the A.S.A., the nature and extent of its membership, and the service it renders its members. In treatment and in format the bulletin cannot be classed as high-pressure promotional literature, and for this reason it will commend itself to the engineer who wants a brief, matter-of-fact exposition of the important work carried on by one of the profession's great joint bodies.

Members of The American Society of Mechanical Engineers should find satisfaction in recalling that the Society undertook its first formal work in standardization in 1885, five years after the formation of the Society and long before there was a National Bureau of Standards in the United States and before the American Standards Association came into being, and in the further fact that it was instrumental in setting up both of these bodies. As in other important undertakings of the Society, noteworthy among which is the work of the A.S.M.E. Boiler Code Committee, mechanical engineers early exhibited a genius for attacking a cooperative program by a typically American method. Time will prove whether or not this method will persist, but at present, as has been pointed out before in these pages, results have proved it to be an important evolutionary factor in regulation as opposed to legislation.

Few persons, least of all engineers, need to be reminded of the far-reaching effects of the impact of science and technology on society and government. The all too natural impulse is to rush to the rescue with hasty and ill-advised legislation; and, in a nation composed of sovereign states and populous municipalities, confusion and irritation result. Standardization and codification are natural steps in eliminating confusion and inefficiency in cases where engineers and industry themselves are primarily concerned, as in the case of the A.S.M.E.'s first efforts to standardize pipe and pipe threads and to provide a "standard method for steam-boiler trials." The next step is to secure public and legal recognition, and to extend the principle and method into fields where public health and safety, in addition to economic advantage, are at stake. By taking the lead before demand for public action arises or as soon as such demand develops, engineering societies and trade associations have had the satisfaction of seeing their standards publicly adopted and their codes used as a basis for intelligent legislation. This is as it should be in a democracy.

If engineers and industrialists are wise they will be alert to the danger of losing what leadership they have exercised and of falling prey to the authoritarian method which solves all problems by passing a law. There is always the possibility that the misguided but well-intentioned reformer may get public acceptance of his scheme, to mention a few cases, for making the legal value of pi 3.25, or for freezing some essentially fluid economic relationship into a fixed value, or for outlawing an inevitable technological development, or for building a bulwark of law and paper against economic deluge.

The problem is more complex than pipe threads and mechanical safety devices. It has come to involve a host of subtle social and economic relationships with such results as were seen in the N.R.A. and are found in the Wagner Act and the Wages and Hours bill, and in attacks on business and the professions. Today it is the issuing and exchange of securities and the public utilities that are under fire—tomorrow it will be private business and industrial power plants. Bankers and physicians are now feeling the lash. How soon will it be before engineers and scientists will smart under it?

ENGINEERING *and* HEALTH

By HARVEY N. DAVIS

PRESIDENT, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

OUR FRIENDS the doctors belong to an appealing profession. They deal with human suffering and work miracles of relief. The practicing physician touches the lives of his patients and their families in times of minor or major crises, brings calm competence for them to lean on, initiates purposeful activity when the urge to do something is especially strong, and renews and strengthens the courage of all concerned. The hospital provides, sometimes a little too impersonally, but nevertheless effectively, a kind of care that the private household can but seldom afford. The research worker in medicine wins dramatic victories over one disease after another by methods that the educated layman can comprehend even if he cannot fully understand the detail of the research technique. To the general public it all seems like a perfect personification of science at its best, working untiringly for the benefit of mankind. Perhaps it is for this reason that, at least in reasonably prosperous times, generous-minded men and women are so easily persuaded to make liberal gifts to hospitals, medical schools, and institutes for medical research.

Our own profession commonly makes no such emotional appeal to the lay public. Our achievements are too often thought of as having an industrial rather than a human significance. The man in the street admires and trusts the engineer in a blind and sometimes extravagant fashion, but this admiration tends to be as cold and impersonal as that which he accords to one of our machines. Does not the engineer deserve a warmer and more affectionate appreciation? If only we could make clear to ourselves and to the public some of the things we are doing or trying to do, that touch intimately the personal lives of men, might we not hope that the respect now commonly accorded us may be tinged with more of the emotion-stirring loyalty that alone can inspire active cooperation?

It is with this thought in mind that I have chosen to inquire to what extent the engineer can be thought of as rivaling the physician in the promotion of health. In appraising this friendly competition, let us not forget that, while the engineer's achievements are never as dramatic, spectacular, or individualized as is the saving of a life or the restoration of a sufferer to vigorous effectiveness, the engineer deals, not with individuals, as do most physicians, but with the great masses of men, women, and children that constitute modern communities. If, then, the intensity factor of his health work is, perhaps, less than that of the physician, its quantity factor is, in general, immeasurably greater. But any appraisal of the effectiveness of any sort of work, in physics or in life, depends on the magnitude of a product containing both an intensity and a quantity factor. If, then, the intensity factors of the various engineering activities that promote health are found to be far greater than that zero which alone could nullify the significant product, it is, perhaps, not unreasonable to suggest that the engineers of today are contributing quite as much to the promotion of health as are the physicians.

The most obvious, because the most direct, contributions of engineers to the promotion of health lie, of course, in the field of sanitation. By bringing abundant supplies of pure water into towns and cities, a boon that only those who have lived or traveled in arid regions can fully appreciate, by building sewers and sewage-disposal plants, by modern methods of refuse collection and disposal, by the invention and fabrication of modern plumbing fixtures which make cleanliness easy, and by a patient persevering fight against atmospheric and stream pollution, engineers have undoubtedly saved many lives and relieved the world of much suffering. While the medical men have had to lead the way in attacking such diseases as hookworm, malaria, and yellow fever, it has been the sanitary work of engineers that has put this hard-won knowledge into practical effect on a large scale over considerable areas. Indeed in the whole field of public-health work and of preventive medicine in which so many forward-looking physicians are actively engaged, engineers are their indispensable allies. The tremendous influence which these various sanitary and other advances have had on the general health level of the population as compared with that which prevailed in the middle ages is too striking to require further comment.

In the important matter of diet also, the work of the engineer has been of importance. By the development of tin plate and of intricate machines for fashioning it, he has made possible the canning of food on a tremendous scale, thus broadening and enriching the diet of the nation, and making available at all seasons, and in the most out-of-the-way places, foods rich in vitamins and hormones. The development by engineers of refrigeration on ships, on trains, in cold-storage warehouses, and in the home, including the newest methods of quick freezing, has contributed to the same end. Irrigation, often involving engineering projects of enormous magnitude, has helped the farmer to produce food in greater abundance and often of finer quality. Still more fundamentally, the ships, trains, and motor trucks, by means of which most of the food of the nation is brought to those who consume it, were invented and developed, and are fabricated and maintained by engineers. Without them no modern urban population could exist. By these means engineers have profoundly affected the dietary habits of whole nations and have made possible the elimination of deficiency diseases and of the lowered resistance to infection that malnutrition causes.

In the matter of housing, also, engineers have played their part. They have improved the materials and methods of construction, and therefore both the availability and the usefulness of buildings of every sort. They have flooded houses, offices, and workshops with eye-saving light. They have provided the central heating plant that insures a uniform controllable temperature throughout a house. Air conditioning is just around the corner. By developing transportation they have enabled an urban population to find over a far-flung area more healthful living conditions than were available even to the well to do of, let us say, two centuries ago.

In all these obvious ways engineers have contributed to the maintenance and improvement of the health of vast numbers of people. This is, however, by no means the whole story. There are certain other activities of engineers that have an even more significant effect on the health level of a nation.

Consider first, all that is involved in what is called a national

Dinner address delivered at the Semi-Annual Meeting, St. Louis, Mo., June 20–23, 1938, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

standard of living. Technical achievements in sanitation, in the production, transportation, and preservation of food, and in housing may determine what is available to those who can afford to have what they want; but it is the national standard of living that determines what the average man actually gets. If the national standard of living is low, there will be bad housing, bad sanitation, malnutrition, a prevalence of deficiency diseases, and a general lowering of resistance to infection that will be responsible for much sickness and many deaths. By far the most effective way of raising the general health level of any population is to raise its standard of living. This problem is, fundamentally, not medical but economic.

The standard of living of a community is nothing else than its production of goods and services per capita per year. Unfortunately this is not always the same as a community's capacity to produce per capita per year. At the moment, for instance, we apparently do not know how to make our economic system function in such a way as to permit men to produce and consume all they could easily produce and would like to consume.

In the long run the actual production of a community per capita per year will be determined by its capacity to produce, and its capacity to produce will be conditioned largely by the possible production per man-hour of expended labor. In other words, in the long run, the only way to raise the standard of living of any community, and with it the general level of the health of that community, is to increase what a man can do in an hour by giving him more inanimate slaves in the form of horsepower and kilowatts, by giving him more and better tools and machines with which to work, by mechanizing and automatizing more of the routine operations in his productive processes, by working out technological advances and inventions that displace some useful thing that is hard to make by something else equally useful and easier to make, by showing h m how to handle things more deftly, and how to postpone or avoid fatigue, and by more effectively organizing the teamwork of the industrial unit in which he works. Only by such means as these can the standard of living of any community be permanently raised, and only engineers can provide these elements in the increased hourly productivity of the workman of today and tomorrow. By raising our scale of living in the future, as they have marvelously raised it in the past, engineers can markedly affect the future health level of the whole population.

Over shorter periods, a high standard of living is characteristic of what we call prosperity. Anyone who ventures to talk about the business cycle is treading on dangerous ground. But it is, I think, generally admitted that a characteristic of most waves of prosperity is the rise of an important new industry. The automobile and the radio are striking examples. What the next new industry will be, no one knows, but it is surely safe to assert that, when it comes, engineers will have been responsible for its genesis and growth. Only industrial activity, energized by the genius of the engineer, can generate good times. If then, it is to engineers that we must look both for the long-term trend, and for the cyclic bulges, in the upward progress of our standard of living, their part in the maintenance and improvement of the health of the nation is great indeed.

All that I have said thus far pertains to the physical health and well-being of mankind. But our friends the physicians know even better than the rest of us the importance of that other aspect of men's lives that may be called mental health. Always important in itself, it often influences, if it does not completely dominate, physical condition. Here too, engineers have important contributions to make in at least two different ways.

The first depends on the fact that a considerable proportion of men and women spend more than a third of their waking hours on an industrial job of some sort. Someone has said that the chief difference between a professional man and a job holder is that the former lives through his work, the latter by means of it. I see no reason why this cynical characterization of industrial work should be accepted as inescapably true, or why such work cannot be made to afford to the worker an acceptable and satisfying way of living. In fact I believe that many workers do thoroughly enjoy their work. We are all too prone to ignore the nonfinancial incentives and rewards of business and industry.

Enjoying one's work is greatly enhanced by, if it is not actually dependent on, having a job that one can do well. This is where the engineers come in. They are beginning to feel their way into new fields of management which involve both adjusting jobs to their holders and assigning men to the right jobs.

Adjusting a job to its holder may be done by a machine designer or by a motion-study specialist. Many modern machines are already designed with special reference to the convenience and comfort to those who are to operate them; though how much remains to be done is indicated by the saying of one of my friends that there is only one machine in the world that is perfectly adapted to the operator, and it took three thousand years to make it so—the machine in question being the ax handle. And to the extent that motion study is used to make jobs easier and less fatiguing, rather than merely to speed up production, it can confer great benefits on the worker.

Assigning men and women to the right jobs holds even greater promise of materially raising the general level of mental health of the working population. Industrial managers are beginning to make notable progress in studying human beings objectively, in measuring individual differences, in appraising both the strengths and the weaknesses of prospective employees, in cataloging the pattern of strengths and weaknesses most appropriate to each particular job, and in assigning men and women to the right jobs. I could tell you, if time permitted, of men who came into an industrial testing laboratory restless and inefficient, sometimes even morose and uncooperative, because they had strong aptitudes of certain kinds on which their jobs made no demands whatever, and how, in many cases, reassignment of these men to jobs that called into play all their aptitudes resulted within a year in almost miraculous alterations in personality and outlook on life. I could tell you of women, trained at their own request as comptometer operators, who become nervous wrecks within a year because of the lack of a certain necessary aptitude which could easily have been detected in advance. Nor should we forget the intangible but often important stimulation to personality that comes from the mere fact that one has been studied and measured, that one's abilities have been sought out and recognized, that one's life has been paid attention to and discussed as an individual adventure. Not that the millenium is immediately at hand by any means; the engineer-managers of today have only just begun to scratch the surface of this highly promising field, and he who tries to go too fast in it will come a cropper, and perhaps temporarily discredit the whole field. Nevertheless I am convinced that this kind of activity will produce, in the next twenty-five years, a greater harvest of human satisfaction and mental health than any of us can yet conceive.

Turning now to the second way in which engineers can hope to help bring more abundant mental health to the world, we find ourselve facing a much more difficult problem. Perhaps I

am over optimistic in even mentioning it as one that engineers or anyone else can hope to solve. And yet, in its various ramifications, it is probably the most important problem that civilization faces today. I refer to the problem of industrial instability, the problem of the recurrent recessions and depressions that periodically throw millions out of work, and disrupt, sometimes permanently, the lives of many of them, the problem of social insecurity.

That social insecurity can profoundly affect the mental, and even the physical health of great numbers of people, is undubitable. Worry has wrecked more lives than tuberculosis, and there is no worry so insistent as that which besets a self-respecting industrial worker, and his whole family, if he thinks there is danger of losing his job, except that of a worker who has lost his job. I suspect that this sort of worry is by far the most important single factor in the American health situation today.

What hope is there of lightening this incubus of fear caused by industrial insecurity? What hope is there of steady, perhaps even of guaranteed employment?

Two types of thinking are current with respect to problems of this sort, one political, in the best sense of that word, the other industrial. It is characteristic of the political type of thinking, whenever a social problem can be defined at all, to attempt to solve it by enacting a law. This type of thinking holds, consciously or instinctively, that social progress can best be forced forward by legislation. This dogma, to those who are persuaded of its validity, is comforting. It affords them an opportunity to do something about it, here and now, without waiting for the slow processes of social evolution. In some cases reform by means of legislation is indeed the only practicable procedure, particularly when a recalcitrant fringe of unsocial competitors has to be whipped into line with the standards which a great majority would be glad to maintain if they could. But to coerce a majority to proceed faster along the path of social progress than they are ready to go, is a process both difficult and dangerous even though alluring. In such a case, education is more to the point than legislation.

The political type of approach to the problems of today may, of course, succeed in remaking our world, particularly if it be reinforced by plenty of emotion-stirring propaganda. It may even lead to the most effective forms of government that the world has yet seen. These new forms of government are, however, almost certain to be highly centralized, closely integrated forms of government, exerting over industry, and over the lives of citizens generally, the detailed regulation and control which seem to be essential to making any planned economy work. Personally, even if I were sure that the political approach would lead to highly efficient governmental forms and to really well-ordered lives, I would rather sacrifice some of this efficiency and orderliness to secure more individual initiative and responsibility, more of a chance for each of us to make his own mistakes and enjoy his own triumphs.

The industrial type of thinking about economic and social problems proceeds in quite a different way. Too often in the past, unfortunately, it has tended to ignore such problems as long as possible, and when at last they loomed up inescapably, it has tried to fight them instead of to solve them. The industrial leaders of today, however, are beginning to have an economic and sociological background with which to think through the remoter human implications of the decisions they make and the policies they pursue. They are beginning to work out, step by step, each in his own business unit, some sort of social justice with respect to the conditions and rewards of industrial work and the effect of it on the whole lives of workers. The industrial type of thinking pins its faith to the hope that all these tiny steps forward, scattered all over the country and through many industries, influencing each the other both by the contagion of example, and by the educational process of thoughtful discussion, will integrate into a march of progress that, however halting and irregular it may at times appear to be, will have firm ground under its feet.

The key to the whole economic and social situation, according to this way of thinking, is the breeding of a sufficient supply of industrial administrators who have not only sound business judgment but also enough social understanding and vision to better adjust the functioning of our present economic and industrial system to the welfare of society at large. Many of us are hoping that such progress will be made rapidly enough to forestall the motivation for, and the possibility of, too much legislative experimentation.

But, you say, where do engineers come into this picture? The answer is that more and more are engineering-trained men finding themselves in positions of executive responsibility in business and industry. There seems to be something about the training and experience of engineers that fits them for such work. Instinctively they deal with facts rather than with traditions and emotional reactions. Their work forces them to see things in the large, to fit details into long-range plans, to see visions and dream dreams, and then to translate them into reality by the careful organization of a multitude of various contributing activities. I believe that engineering-trained men are destined to contribute far more than their proportionate share of the industrial leaders of the next quarter-century. If so, they are facing a great opportunity and a great responsibility. If they can learn to think around their jobs as well as thinking their jobs through, if from their natural vantage point as liaison officers between capital and labor, they can get a comprehensive vision of the aims, aspirations, points of view, and prejudices of both groups, if from their familiarity with the flow of materials through a factory or the flow of energy through a power plant they can derive a vivid picture of the flow of goods and of money through the channels of production and consumption, if their experience in handling men on the job can bring to them some understanding of how men want to live, they can, perhaps, contribute more than any other single group to the solution of those fundamental economic and social problems of which we have been speaking. And if by these means they can, even to a small extent, diminish the worries inherent in industrial insecurity, they will have made the greatest contribution of the century to the promotion of the mental health of vast numbers of people.

May I, then, suggest that he who is profoundly interested in maintaining and improving the health of mankind, and who has enough vision and imagination to sense the long-time trends of life, would do well to devote a considerable part of his energy, or of his beneficence, to fostering engineering education and research. In particular he should be interested, not only in the technical aspects of the profession, but especially in those branches of it which are concerned with industrial management and with the foundations on which sagacious industrial administration must rest. The results will not be so easy to observe, so directly and immediately obvious, as if he had been instrumental in training a succession of wise physicians or skilful surgeons, or in conquering some obscure disease, but in the long run, he will accomplish much improvement in both the physical and the mental health of his fellow men.

A New Method in TOOLING AUTOMATIC SCREW MACHINES

By E. W. BRINKMAN

DAVENPORT MACHINE TOOL COMPANY, ROCHESTER, N. Y.

CHANGES in the tooling of automatic screw machines have developed rapidly, particularly in the last five years. The necessity for time saving in operation, increased cost of machinery, and higher labor costs have made these developments necessary. We, naturally, have been vitally interested in these developments, and, while this paper is not in any sense meant to be an exposition of our own particular equipment, reference to it, at times, must be made for illustrative purposes only. Some features pertaining to the tooling of automatic screw machines should be more widely known than they are at present. This paper is presented as proof that the most essential part of efficiently operating machine tools, and particularly automatic screw machines, is in using the correct tools for the job.

In a great majority of cases, altogether too little study is given the actual tooling of individual jobs, and it is not unusual for a manufacturer to purchase a high-priced machine tool because he feels that it is necessary to control his product and yet not purchase the additional equipment which might be required to reduce the cost of producing the part sometimes as much as 75 per cent, despite the fact that the cost of the additional equipment might be only a small item in proportion to the cost of the machine itself.

As an illustration, a manufacturer was prepared to buy several automatic screw machines the price of which, with the motor drive and the necessary tools required, was approximately $6000 each. By adding to this equipment additional tooling valued at approximately $500, the cost of producing the part could have been reduced from 2 cents per unit to 1 cent. The customer's contention, however, was that the additional equipment which was recommended would be too complicated for his operators to handle on the basis of one operator running three machines. It is perfectly obvious that, if by adding additional tools to a machine a second handling can be saved, it will reduce the net production cost as compared with the gross. Often a substantial saving is effected, owing to the fact that the part does not require an expensive second operation. Even though it were necessary to reduce the number of machines cared for by one operator, the reduction in cost per finished piece would more than compensate for this expense.

This is especially true on machines producing small brass and steel parts under 1 in. in diameter from round stock, since, in a great many instances, these parts are produced at rates of anywhere from 1500 to 9000 pieces per hour. In the handling of second operations, it is difficult for the operator to produce on the average more than 1000 pieces per hour. Not only does this require an additional operator but also in a great many instances additional equipment in the form of machines and special holding fixtures. These are eliminated entirely when the parts are of such a character that they can be completed in one operation, on an automatic screw machine.

Presented at a meeting of the Machine Shop Practice Division, Rochester, N. Y., May 10–12, 1938, of The American Society of Mechanical Engineers.

USING OPPOSED SPINDLES ELIMINATES SECOND HANDLING OF WORK

The remainder of this paper will be devoted to showing a recent development for eliminating the second handling of parts and deals particularly with a principle that was applied some forty-odd years ago by the late William Simeon Davenport for the production of fine clock pinions. This mechanism consists of having two opposed spindles mounted in a horizontal plane, synchronized to run at the same speed in the same direction, each having its own independent chucking mechanism.

It was not until a few years ago, however, that this same principle was applied to multiple-spindle screw machines. Fig. 1 is an end view of a five-spindle, automatic screw machine with four cross slides in their respective cutting positions. These cross slides are operated from a cam shown in the lower left-hand part of the figure; the upper left spindle is shown in the cutting-off position. It is in this position that the opposed spindle is mounted. Fig. 2 shows the side elevation of a portion of the machine and the opposed spindles. That at the left is the work-carrying spindle in the cutting-off position and the right spindle is the one that chucks the work before it is severed from the bar, supporting and driving it during the cutting-off and other subsequent operations. The cam mechanism at the lower right controls the chucking mechanism as well as positioning the spindle.

Fig. 3 shows a part that was being produced in two operations. The first consisted of blanking the part, drilling the hole from bar stock, and cutting off the part. A second handling was necessary to finish the spherical surface. Since it was desirable that the part be completed in one operation, it was decided, after considering various ways and means, to mount a supporting spindle directly opposite the work spindle which would carry its own independent chucking mechanism. This method of producing the part was so successful that other uses for this type of equipment were soon developed.

With this method of supporting a part while it is being cut off, it is possible to feed the cutoff tool in a good many instances twice as fast as it could normally be fed, and, in cases where cutting off is the longest operation, production time can be reduced nearly 50 per cent. Then too, tool life is also increased considerably since the number of surface feet that the tool is in contact with the work, due to the heavier feed, is reduced. Normally, when a cutoff tool is the least bit dull, it is necessary to regrind it due to its leaving a large cutoff burr. With this method, the tool can be very dull before regrinding is necessary.

The first auxiliary spindle that was developed was simply a holding spindle which would only drive work in the forward-most position. It was later decided that, if an independent chucking mechanism which could be controlled in any part of the cam circle could be developed, it would be possible to do

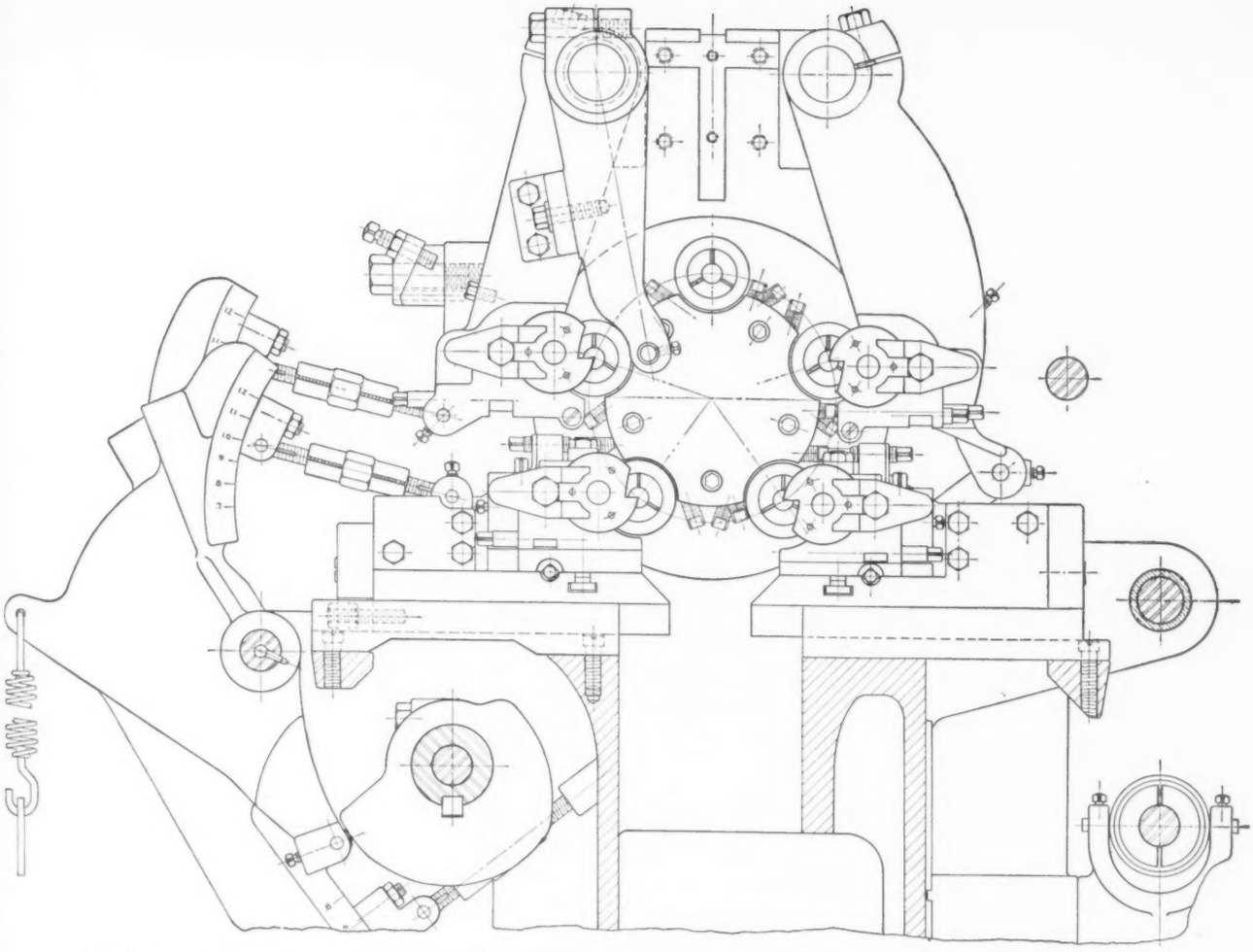

FIG. 1 END VIEW OF A FIVE-SPINDLE, AUTOMATIC SCREW MACHINE WITH THE FOUR CROSS SLIDES IN THEIR RESPECTIVE CUTTING POSITIONS

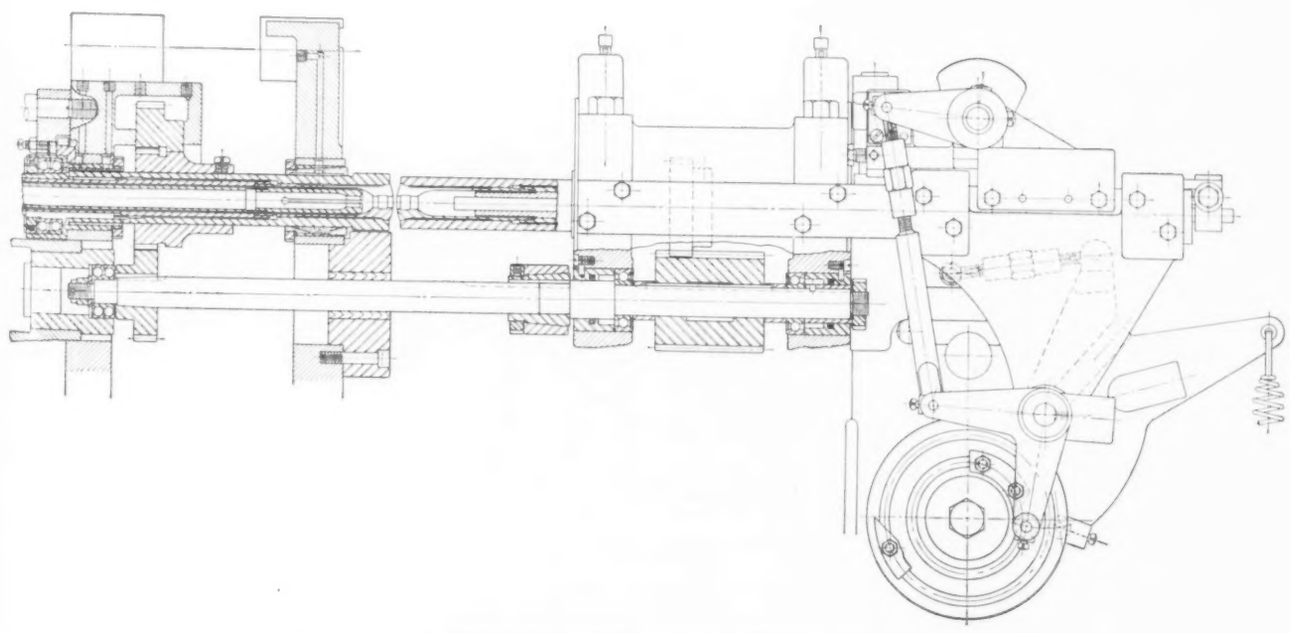

FIG. 2 PARTIAL SIDE ELEVATION OF THE MACHINE, SHOWING THE OPPOSED SPINDLES

other operations on the cut-off end of a part without necessitating a second handling.

After considerable development work, the mechanism shown in Fig. 2 was developed which not only chucked the part in its forward position, driving it while it was being severed from the bar, but also permitted withdrawing the work to any position within the range of the longitudinal movement, which would permit moving a tool in a coaxial position and feeding the tool into the work on the cut-off end or the rotating work onto the stationary tool. The decided advantage in producing the finished piece in this manner was that the chucking of the work, preferably on a turned surface, before it was severed from the bar, made it possible to do second operations such as counterboring, drilling, and trepanning and maintain unusually close concentricity tolerances. Such close tolerances were previously difficult to maintain, especially in second operations where the work was stationary and the tools rotated.

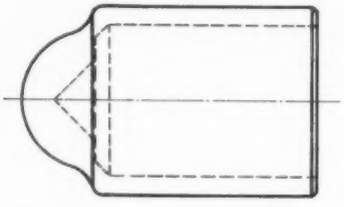

FIG. 3 A PART THAT FORMERLY REQUIRED TWO OPERATIONS BUT IS NOW PRODUCED IN ONE BY USING OPPOSED SPINDLES

Even when operations of this kind were performed in chucking machines where the work rotated and the tools were stationary, it was necessary to have unusually accurate chucking mechanisms and provide an accurate stop, especially where operations of counterboring and trepanning had to be held to unusually close tolerances for depth as well as concentricity. These conditions are automatically eliminated by using the mechanism shown, since the movement of the spindle that grips the part is automatically controlled by the height of its cam as well as an adjustable stop. This entirely eliminates the errors that might occur in a second operation due to handling.

An illustration of accurate depth tolerance is shown on the part at the left of Fig. 4 and concentricity and accurate reaming tolerances are shown on the part at the right. These are only a few of the parts that can be finished in one operation with such equipment and that previously required two or more operations.

EQUIPMENT CAN BE ADAPTED TO A WIDE VARIETY OF WORK

An example of the adaptability of this type of equipment to various classes of work is shown in Fig. 5 at the top. This part is a carburetor needle that required an accurate turning tolerance on the tapered seat. The necessary concentricity tolerance had to be held from the radius section of the part shown in the end view.

The previous method of producing this part was to make the blanks in a regular screw machine and finish-turn the point in a precision turning machine. The particular objection to this was not only the additional cost in handling these parts but also that it was difficult to maintain the accurate tolerance required between the seating point of the needle and the opposite end, which controlled the position of the float in the carburetor. By holding the tolerance on the nose of the spindle to within less than 0.0001 in. concentricity and using the nose of the spindle as a guide for the turning tool, it was possible not only to complete the part in one operation but also to hold more uniform tolerances on the length and also hold the concentricity tolerance on the tapered end well within specifications.

At first thought, it would seem rather expensive to try to maintain the accuracy on the nose of the spindle, but, in actual practice, it is not, owing to the simplicity of the spindle which runs in plain bronze bearings. In actual practice, the tolerance required on the point was maintained with one of these spindles over a period of more than nine months. As a matter of illustration, the cost of this spindle is less than $30 and the cost of adding the total equipment to the machine is approximately $600. The use of it not only permitted eliminating this secondary finish-turning operation but also a burnishing operation on the radius end and a broaching operation, both of which had to be done after the blanking operation and prior to the finish-turning. The machines saved by producing this part in this manner were a polishing machine, a small punch press for broaching, and a precision turning machine. Previous to the introduction of this new method, work of the nature just mentioned would never be considered for a screw machine of any kind and least of all a multiple spindle. This job has been operating successfully for more than a year.

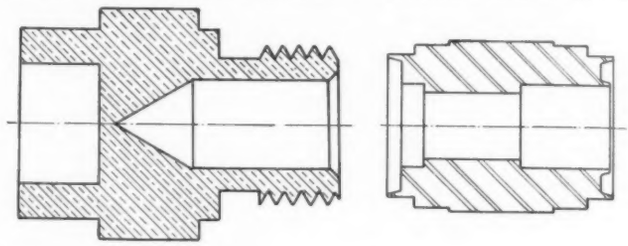

FIG. 4 TWO EXAMPLES OF ACCURATE TOLERANCES ON PARTS PRODUCED IN AN AUTOMATIC SCREW MACHINE EQUIPPED WITH OPPOSED SPINDLES

(The piece at the left requires the depth to be held within close limits, while concentricity and accuracy of reaming are the important factors in the piece at the right.)

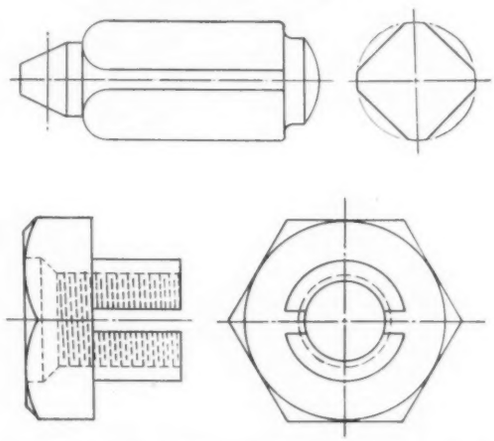

FIG. 5 ANOTHER PAIR OF PARTS SHOWING THE ADAPTABILITY OF OPPOSED-SPINDLE TYPE OF EQUIPMENT

(The carburetor needle shown at the top requires an accurate turning tolerance on the tapered seat. In the lower part, tapping, which is the final operation, was complicated by the slot and the countersinking at both ends. Use of an automatic screw machine with opposed spindles eliminated three machines in one case and four in the other.)

Another illustration of the possibilities of tooling and using this type of spindle was developed for the part shown at the

(Continued on page 702)

HEAT TRANSFER *to* BOILING LIQUIDS

By E. T. SAUER, H. B. H. COOPER, G. A. AKIN, and W. H. McADAMS

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IT HAS BEEN widely believed (*a*) that the rate of boiling per unit area increases faster than the over-all temperature difference, i.e., that the over-all coefficient of heat transfer U increases with increase in temperature difference Δ, (*b*) that the use of a metal of lower thermal conductivity will reduce the heat-transfer rate, and (*c*) that fouling of the surface reduces the rate of heat transfer.

The purpose of this paper is to describe the progress in a program initiated over two years ago, and to show that these widely accepted generalities are by no means always true.

In the past most of the experimental work on boiling has been confined to water or aqueous solutions, using relatively small over-all temperature differences, which gave relatively small rates of heat transfer per unit heating surface. This work covered the cases ordinarily encountered in multiple-effect evaporators. Recently, engineers have become interested in far higher rates of heat transfer; furthermore in boiling organic liquids with low boiling points, large temperature differences are encountered even when exhaust steam is used.

It has recently come to light that as the over-all temperature difference is increased, the rate of heat transfer at first rises rapidly, then increases more slowly, goes through a maximum, then drops rapidly, and finally increases (1).[1] Actually there are two mechanisms by which boiling can occur. With small temperature differences the liquid in contact with the hot metal surface becomes superheated and small bubbles form on the surface. During the time the bubbles are in contact with the metal, they grow rapidly and finally break away from the surface. When the temperature differences are much larger, the liquid does not come in contact with the metal, but is separated from it by a layer of vapor which forms an insulating blanket through which the heat must be transferred. The mechanism is the same in principle as that of the drop of water which dances about on a red-hot stove for a long time before evaporating, due to the slow rate of heat transfer by conduction and radiation through the insulating vapor film. While this phenomenon has been common knowledge for many years, it is surprising that the same phenomenon is encountered when the temperature of the surface is only from 30 to 100 F above the boiling point of the liquid. The temperature difference at which the rate of heat transfer goes through a maximum will be called the critical temperature difference. The maximum rate of heat transfer occurs where the coefficient of heat transfer starts decreasing more rapidly than the temperature difference is increasing.

NOTATION

Q = total heat transfer, Btu
A = area tube outside surface, sq ft
Θ = time, hr
Δ = over-all temperature difference, condensing steam to boiling liquid, deg F
Δ_L = temperature difference, tube outside surface to boiling liquid, deg F
U = over-all coefficient of heat transfer, Btu per hr per sq ft per deg F
h = coefficient of heat transfer from tube outside surface to boiling liquid, Btu per hr per sq ft per deg F
$Q/A\Theta$ = rate of heat transfer, Btu per hr per sq ft

Fig. 1 shows the results obtained with a laboratory apparatus boiling benzene at atmospheric pressure on a steam-heated chromium-plated copper tube. It is noted that the over-all coefficient reached a maximum at an over-all temperature difference of 80 F, but that the rate of heat transfer reached a maximum at an over-all temperature difference of 100 F.

Fig. 2 illustrates the first mechanism of boiling ethyl acetate on a steam-heated aluminum tube. Except for the bottom portion of the tube which may have had a lower effectiveness due to condensate, it appears that vapor is being generated in relatively small bubbles at a number of points on the heating surface.

Fig. 3 shows ethyl acetate boiling with an over-all temperature difference of 73 F which gave a rate of 41,200 Btu per hr per sq ft, the maximum rate obtainable with over-all temperature differences ranging from 48 to 122 F.

Fig. 4 is a photograph of the same tube and liquid, but with an over-all temperature difference of 122 F. This increase in the

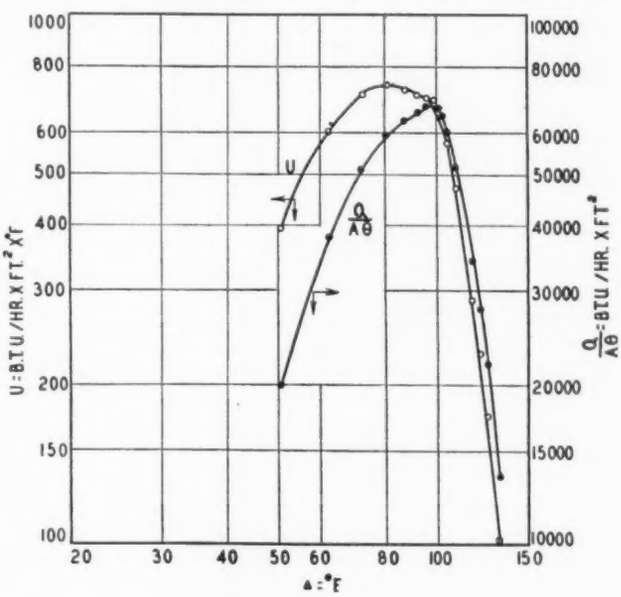


FIG. 1 OVER-ALL HEAT-TRANSFER COEFFICIENTS AND HEAT LOADS FOR BENZENE BOILING ON A STEAM-HEATED CHROMIUM-PLATED COPPER TUBE, SERIES 1

[1] Numbers in parentheses refer to the Bibliography.

Contributed by the Heat Transfer Group and presented at the Annual Meeting, New York, N. Y., Dec. 6 to 10, 1937, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

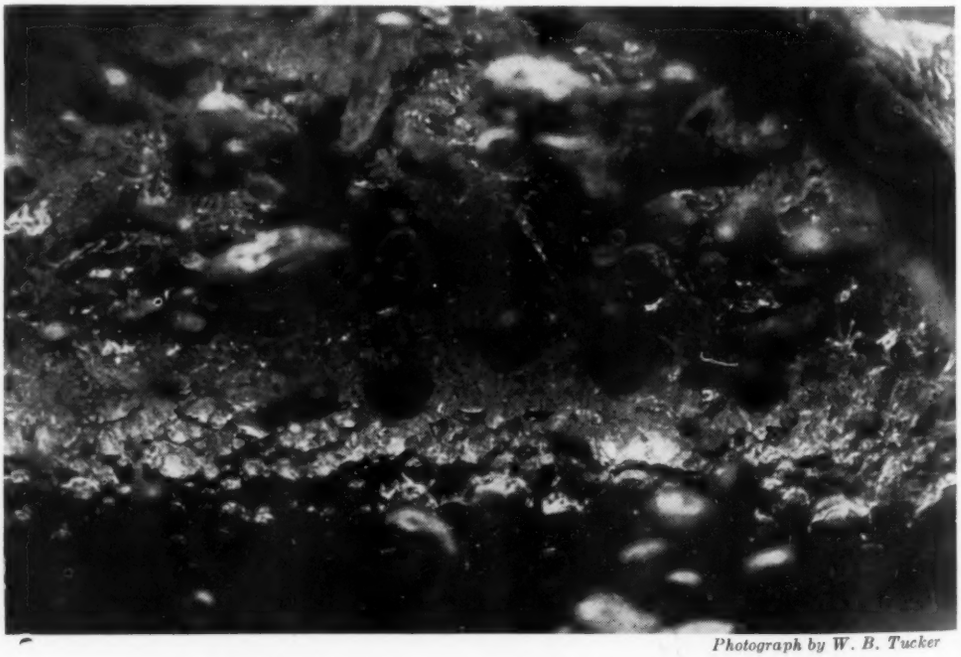
Photograph by W. B. Tucker

FIG. 2 ETHYL ACETATE BOILING ON A $^1/_2$-IN. OD ALUMINUM TUBE
(Δ = 48 F, $Q/A\Theta$ = 26,000, U = 540.)

temperature difference was accompanied by a decrease in the rate of heat transfer from 41,000 to 5700 Btu per hr per sq ft, and the over-all coefficient was reduced from 560 to 47. As is seen from the photograph, vapor is generated no longer in small bubbles on the surface, but in a vapor film entirely surrounding the tube. In the actual apparatus the light reflected from the interface between the vapor film and the main body of the liquid could readily be seen, and one got the impression of looking at a chromium-plated tube, even when a tarnished copper tube was used. Obviously, vaporization occurred at the interface of the vapor and liquid, and the vapor rose through the film and broke away from the tube in large flat bubbles. Neglecting the other thermal resistances, and using 0.0087 as the thermal conductivity of the vapor, the effective thickness of the vapor film was approximately 0.002 in.[2] At these low temperatures the correction for radiation is negligible, whereas, in quenching from high temperatures, radiation plays an important rôle, especially in the early stages.

One must be careful in boiling liquids of low boiling point with steam-heated tubes, not to use too high a steam pressure. Thus in the run corresponding to Fig. 4 where the gage steam pressure was 40 lb per sq in., the heat-transfer rate was only 14 per cent of that in the run illustrated by Fig. 3 where the gage pressure was 12 lb. Even with steam at 2 lb the rate of boiling was 450 per cent of that with 40-lb steam.

These experiments, and others to be described, were made in a laboratory apparatus. The boiler consisted of a vertical glass cylinder $3^1/_2$ in. diam and 7 in. high. Above the boiler there was a spherical glass vapor-disengaging section of 7 in. diam. In the top of the vapor dome were three openings. The first permitted the insertion of a thermometer, immersed in the liquid, the second led to a reflux condenser, and the third was provided for lead wires to thermocouples on the surface of the tube. The thermocouples did not prove entirely satisfactory, and hence only over-all coefficients are reported from tests with this equipment. Two openings in the sides of the boiler permitted the heating tube to be inserted through glass nozzles and stoppers horizontally across the diameter of the cylindrical boiler. Two windows of optically plane glass, placed at the same level as the tube, provided a means of obtaining an undistorted view of the conditions in the still, and of photographing the tube at right angles to its axis. Except for the two windows the boiler and vapor dome were insulated.



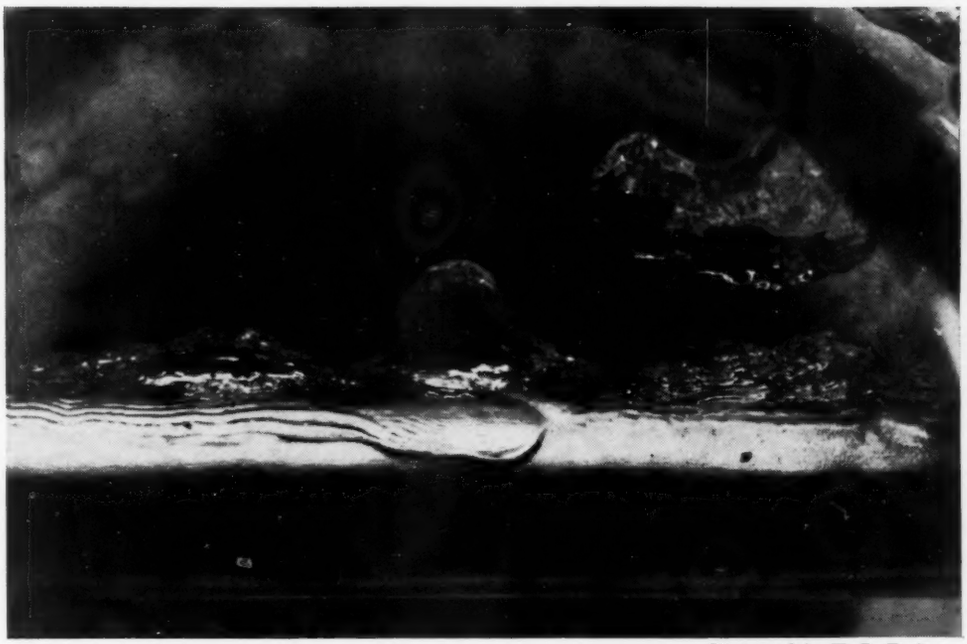
Photograph by W. B. Tucker

FIG. 3 ETHYL ACETATE BOILING ON A $^1/_2$-IN. OD ALUMINUM TUBE
(Δ = 73 F, $Q/A\Theta$ = 41,200 = maximum, U = 560.)

[2] If, due to disturbances in the film, the effective thermal conductivity is higher than the value used, the film thickness would be greater than that calculated.

In the first series of experiments (5), the heating tube was supplied with steam at not more than 45 lb per sq in. gage pressure (condensing temperature, 292 F). In the second series (6) the tube was supplied with steam at a maximum pressure of 180 lb per sq in. gage (condensing temperature, 379 F). The rate of water flow through the reflux condenser was found by measuring the time for the water to fill a calibrated bottle; and the temperatures of the water as it entered and left the condenser were measured by thermometers graduated in divisions of 0.1 C, inserted into the inlet and outlet lines of the condenser.

A calibrated pressure gage was attached to the steam line supplying the heating tube, and a thermometer was placed in the steam line after a superheating section. In the second series of experiments an additional thermometer, followed by a condenser, was placed in the steam line after the test section. This condenser was used to condense excess steam passing through the test section. In both series, steam traps were used to allow collection of the condensate.



Photograph by W. B. Tucker

FIG. 4 ETHYL ACETATE BOILING ON A $^1/_2$-IN. OD ALUMINUM TUBE
(Δ = 122 F, $Q/A\Theta$ = 5700, U = 47.)

Satisfactory heat balances were obtained. The results reported are based on the heat load on the reflux condenser, corrected for the relatively small heat loss through the walls of boiler and vapor dome. Heating tubes of various metals were used in different runs, but all of those used in tests of series 1 and 2 had an outside diameter of $^1/_2$ in. The heating tube was exposed to the liquid in the boiler for a length of approximately 3.6 in., giving 0.039 sq ft of outside surface. The values of $Q/A\Theta$ are reported in Btu per hr per sq ft of outer surface. The over-all temperature difference Δ is the difference between the saturation temperature of the steam and the boiling point of the liquid, expressed in degrees Fahrenheit. All runs reported herein were made at atmospheric pressure.

In the first series of experiments tubes made of three metals were used, aluminum, copper, and chromium-plated copper. All had a wall thickness of $^3/_{64}$ in. The surfaces of the copper and aluminum tubes were cleaned with steel wool before each set of runs, and the condition of the tube after the runs were completed is shown under the plots. The chromium-plated copper tube was rubbed off with a clean dry cloth before each series of runs. One of the copper tubes was cut around its circumference with grooves $^1/_{64}$ in. wide and $^1/_{64}$ in. deep, with $^1/_{16}$-in. center spacing. In the second series of runs, tubes of iron (cold-drawn steel tubing), copper, and chromium-plated copper were used. These tubes had a wall thickness of $^1/_{16}$ in., and, with the exception of the chromium-plated copper tube, were cleaned before each set of runs with No. 00 sandpaper. The chromium-plated copper tube was cleaned as before.

The results of these tests are shown in Figs. 5 to 12 in which the over-all heat-transfer coefficients have been plotted against the over-all temperature difference.

Since the thermal conductivity of iron is from 10 to 20 per cent of that of copper, with a given over-all temperature difference in the range where the over-all coefficient increases with increase in temperature difference, the iron would be expected to give the lower over-all coefficient and the lower heat flux, unless the surface conditions differed. From Fig. 5, showing data of series 2 for water, it is seen that the iron tube gave higher over-all coefficients than either copper or chromium-plated copper in the range from 30 to 135 F temperature difference. Since the steam used promotes condensation dropwise on copper, but not on iron, the inside resistance should have been higher with iron than with copper. Since the iron tube gave the lower over-all resistance, the outside resistance for the iron tube must have been enough less than that for the copper to more than offset the larger steam-side and tube-wall resistances. It is believed that the smaller liquid-side resistance is due to the fact that the surface of the iron is more favorable to the formation of a large number of small bubbles than the surfaces of the other two tubes.

The results of series 2 for these three metals with methanol and benzene are plotted in Figs. 6 and 7, and because of the low boiling points of these liquids, the smallest over-all temperature differences are higher than those in Fig. 5.

Figs. 8 to 12 show additional results for series 1 for various liquids and metals. From a study of Figs. 5 to 12, it is noted that for a given liquid the critical over-all temperature difference is not the same for various metals. In Fig. 10, it is interesting to compare the curve for grooved copper with that for plain copper, with ethanol being boiled in both cases. It is seen that the grooved copper gave higher over-all coefficients than plain copper, which is in qualitative agreement with work of Jakob and Fritz (4) with gridded plates. In Fig. 11 it is noted that the over-all coefficient for aluminum and water varied only slightly in the range from 20 to 80 F. When boiling ethyl acetate, benzene, ethanol, and water, the maximum attainable heat flux was always greater with copper or chromium-plated copper than with aluminum tubes. With one exception, the maximum heat flux with a given liquid was higher

with chromium-plated copper than with copper tubes. The maximum rates of heat transfer are summarized in Table 1.

TABLE 1 MAXIMUM RATES OF HEAT TRANSFER
(Btu per hr per sq ft)

Series	Liquid	Tube	$Q/A\Theta$ Maximum
1	Ethyl acetate	Aluminum	41200
1	Benzene	Copper	43400
1	Benzene	Aluminum	50600
1	Heptane	Copper	53100
1	Ethyl alcohol	Aluminum	54800
1	Carbon tetrachloride	Copper	58600
1	Ethyl acetate	Copper	61400
1	Benzene	Cr-copper[a]	68900
2	Benzene	Copper	69400
2	Benzene	Cr-copper[a]	76700
1	Ethyl acetate	Cr-copper[a]	77000
1	Ethyl alcohol	Copper	80400
2	Benzene	Iron	81500
2	Methyl alcohol	Cr-copper[a]	111000
1	Ethyl alcohol	Grooved copper	118000
1	Ethyl alcohol	Cr-copper[a]	124000
2	Methyl alcohol	Copper	125000
2	Methyl alcohol	Iron	155000
3	Water	Copper	198000
2	Water	Copper	268000
2	Water	Cr-copper[a]	321000
2	Water	Iron	413000

[a] Chromium-plated copper.

Inasmuch as the runs of series 1 and 2 were made in the same apparatus by different observers, one working in the spring and the other in the summer, it will be interesting to compare the results for the cases where both used the same metal and liquid. Failure to obtain reasonably good checks on the over-all coefficients in some cases is believed to be due to two main difficulties:

(*a*) Uncontrolled variations in the steam-side coefficient. Variation in the concentration of dropwise condensation promoters present in the steam is known to cause variation in the steam-side coefficient when the inside of the tube wall is made of copper. Variation in noncondensable content of the steam is a possibility.

(*b*) Variations in the surface conditions. Copper was found to give widely varying over-all coefficients, depending on the length of the time since cleaning, even though the amount of foreign matter deposited was barely perceptible.

Table 2 from series 1 shows that the over-all coefficient from steam to water with an initially clean copper tube increased 350 per cent during the first 140 min of boiling, during which time the over-all temperature difference remained constant at 79 F. At the beginning, bubbles formed at only a few points on the top of the tube, but as the run progressed, vaporization occurred at more and more points on the tube until finally the entire surface appeared to be evolving vapor bubbles with considerable violence.

TABLE 2 WATER ON COPPER TUBES, SERIES 1

Run no.	Time,[a] min	$Q/A\Theta$	Δ	U
1	0	90300	78.7	1150
2	25	211500	78.7	2680
3	39	242000	78.7	3070
4	49	267000	78.7	3390
5	78	301000	78.7	3820
6	118	394000	78.7	5000
7	142	409000	78.7	5190

[a] After start of run.

A comparison of Figs. 5 and 11 shows that series 2 with water on copper gave over-all coefficients less than half those of series 1. This may have been due to differences in cleaning the two tubes or to the vagaries of copper mentioned earlier. A similar comparison for data of methanol on copper shows that the results of series 2, Fig. 6, are somewhat more than double those of series 1, Fig. 12, at the larger temperature differences. The data of series 1 and 2 for benzene on chromium-plated copper tubes, Figs. 9 and 7, show better agreement in this case than in the runs in which copper tubes were used. Baker (8) boiling methanol in a steel still containing 2.15 sq ft of heating surface made of 1-in. standard steel pipe, when using the highest available over-all temperature difference (137 F), obtained a heat flux 73 per cent of the maximum obtained in the small apparatus used in series 2.

In a third series of experiments a different apparatus was used. The boiler consisted of a welded steel box 8 in. on each edge. The heating tube passed horizontally through the box along an axis 2 in. from the bottom and water covered the tube for a height of 1 in. The boiler was connected to a reflux condenser and the rate of heat transfer was measured by the same procedure used in series 2. In order to prevent excessive corrosion in the boiler, the entire box was heavily tinned. Windows were provided for observing the boiling, and with the exception of the windows the entire apparatus was heavily lagged.

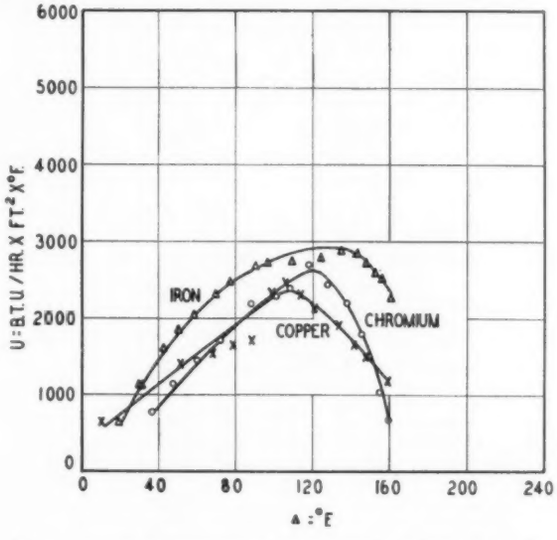


FIG. 5 OVER-ALL COEFFICIENTS FOR WATER BOILING ON STEAM-HEATED METAL TUBES, SERIES 2
(Thin black scale present at end of runs.)

The heating tubes were $^1/_2$-in. standard iron-pipe-size copper tubing and were provided with from three to six thermocouples to measure the surface temperatures. The thermocouples were of the single-wire variety, using Ideal thermocouple wire and the heating tube itself as the hot junction. Holes of 0.02 in. diam were drilled into the tube parallel to a diameter, but offset from the center enough to prevent their going through the inside surface. They were drilled nearly through to the outside surface again. The holes were filled with molten tin and the Ideal wires, insulated, except for a tip, by Pyrex capillary tubing sealed around the wire, were shoved into position. The thermocouple wire outside the tube was insulated by bakelite cement. Equal numbers of couples were installed at top and bottom of the tube, in the same vertical planes. When four couples were used the couples were located 2 in. from either end; later one pair of top and bottom couples was installed midway along the tube. It is believed that the temperatures read by these thermocouples were accurate to

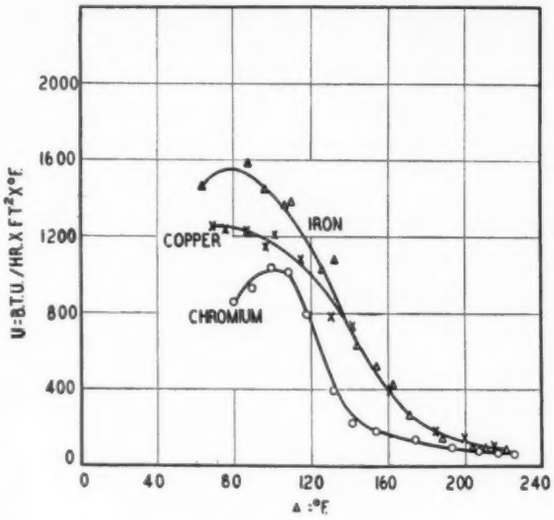


FIG. 6 OVER-ALL COEFFICIENTS FOR METHYL ALCOHOL BOILING ON STEAM-HEATED METAL TUBES, SERIES 2
(Thin brown or black scale present at end of runs.)

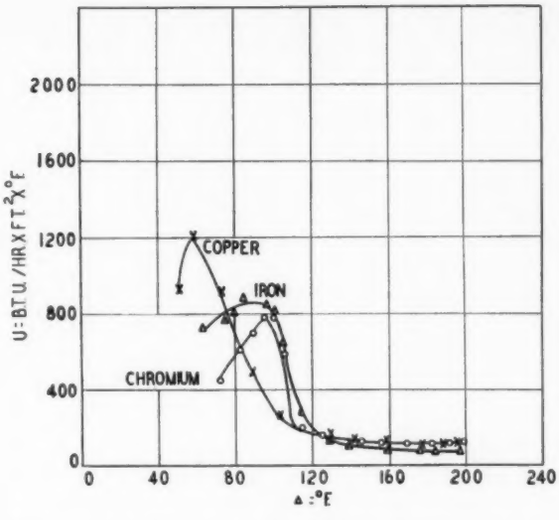


FIG. 7 OVER-ALL COEFFICIENTS FOR BENZENE BOILING ON STEAM-HEATED METAL TUBES, SERIES 2
(Thin brown or black scale present at end of run.)

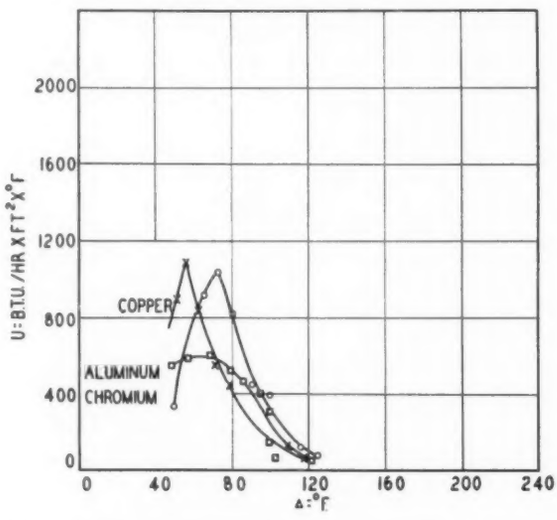


FIG. 8 OVER-ALL COEFFICIENTS FOR ETHYL ACETATE BOILING ON STEAM-HEATED METAL TUBES, SERIES 1

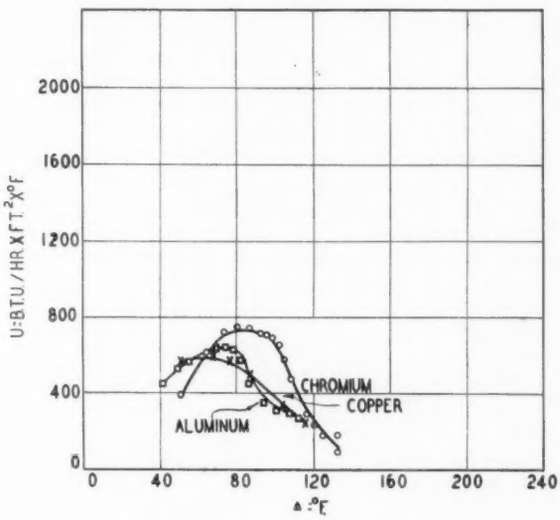


FIG. 9 OVER-ALL COEFFICIENTS FOR BENZENE BOILING ON STEAM-HEATED METAL TUBES, SERIES 1

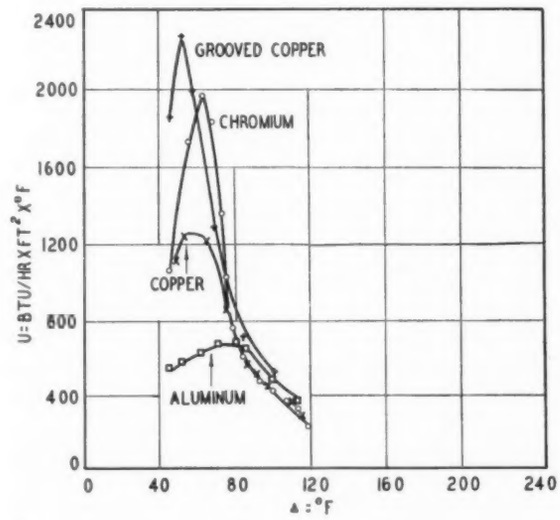


FIG. 10 OVER-ALL COEFFICIENTS FOR ETHYL ALCOHOL BOILING ON STEAM-HEATED METAL TUBES, SERIES 1

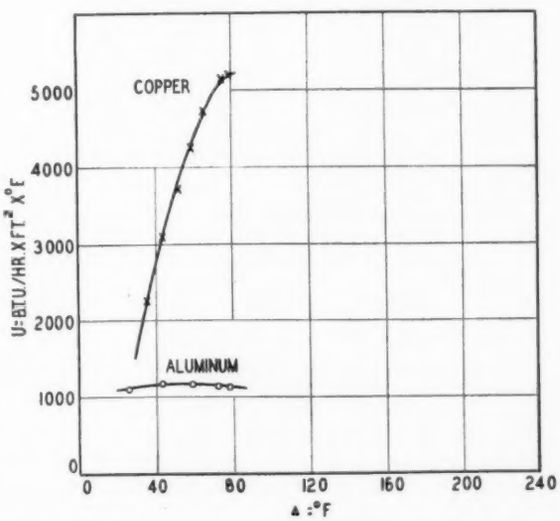


FIG. 11 OVER-ALL COEFFICIENTS FOR WATER BOILING ON STEAM-HEATED METAL TUBES, SERIES 1

within 5 per cent based on the water-side temperature differences, although there was much more than a 5 per cent variation in the temperature difference at various points along the tube.

The temperature differences on which the water-side coefficients of heat transfer were based, were the arithmetic mean of those measured at several points along the tube. Table 3 gives the results of four sets of runs with this apparatus, with distilled water boiling at atmospheric pressure.

TABLE 3 WATER ON COPPER TUBES,[a] SERIES 3

Run no.	Tube no.	$Q/A\Theta$	Δ	Δ_L	U	h	x note [d]
1*b*	1	100000	102	55	1040	1940	33
1*c*	1	48000	124	102	388	472	3.1
1*g*	1	116000	80	65	1250	1730	43
1*h*	1	97500	86	61	1140	1610	5.4
1*j*	1	63000	92	82	740	830	2.7
1*k*	1	137000	66	41.5	2080	3310	16
1*l*	1	137000	74	52.3	1860	2625	26[f]
1*n*	1	52500	45	24	1160	2180	3.6
2*a*	1[b]	57000	50	26.1	1135	2170	10
2*b*	1	49500	43	25.6	1150	1930	8.1
2*c*	1	36500	36	23.8	1010	1530	7.7
2*d*	1	30600	30	20.9	1020	1460	5.8
2*e*	1	24800	26	19.5	950	1270	5.4
2*f*	1	19700	24	17.4	820	1130	5.4
2*g*	1	13800	18	14.0	770	990	4.9
2*h*	1	74000	51	29.2	1460	2540	11
2*i*	1	87500	57	32.3	1530	2700	14
2*k*	1	116000	59	36.8	1970	3160	20
2*l*	1	137000	63	38.3	2180	3590	22
2*m*	1	149000	69	39.2	2160	3780	23
2*n*	1	107000	75	53.0	1430	2020	34
2*p*	1	99000	86	63.0	1160	1570	43
2*q*	1	49000	98	92.0	495	530	5.4
2*r*	1	28400	23	18.7	1220	1500	3.3
4*a*	2[e]	198000	70	46	2800	4300	20
4*b*	2	157000	61	43.1	2560	3630	22
4*c*	2	101000	46	34.2	2200	2950	15
4*d*	2	69000	38	28.2	1820	2450	11
5*a*	2	20200	16	11.7	1260	1720	5
5*b*	2	28000	19	13.0	1470	2150	6.3
5*c*	2	41300	25	17.5	1650	2360	7.2
5*d*	2	69000	32	22.0	2160	3130	9
5*e*	2	85500	36	25.9	2380	3300	9.9
5*f*	2	101000	40	29.0	2530	3490	11
5*g*	2	127000	48	32.4	2650	3920	11
5*h*	2	163000	54	37.3	3020	4360	15
5*j*	2	189000	61	42.4	3100	4450	18
5*k*	2	220000	69	47.1	3180	4670	22
5*l*	2	247000	76	51.6	3240	4780	22
5*m*	2	246000	82	55.9	3000	4400	20
5*n*	2	243000	87	62.7	2790	3870	39
5*p*	2	235000	93	66.2	2530	3550	45
5*q*	2	228000	98	67.7	2340	3380	45
5*r*	2	190000	108	82.8	1770	2300	50
5*s*	2	149000	119	92.5	1250	1610	41
5*t*	2	119000	132	113.6	900	1050	33

[a] Tubes, 1/2-in. standard iron-pipe-size copper tubing, 0.840 in. outside diameter.

[b] Four surface thermocouples were used in runs 1*b* to 1*n*, inclusive. One of the top couples was broken at the end of run 1*n*, leaving three couples for runs 2*a* to 2*r*, inclusive.

[c] Runs 4*a* to 5*t*, inclusive, were made on a second tube provided with six surface couples.

[d] x = maximum difference in reading of any two surface thermocouples, deg F.

Before each of the first three sets of runs the heating tube was polished with No. 500 carborundum dust, and the apparatus was run for several hours before any data were taken. At the end of each of these runs the tube appeared slightly tarnished, but did not have a scale deposit. Before run 5*a*, however, the tube stood covered with water in the boiler for two weeks. It was not cleaned, and was noted to be scaled before the run. When the tube was removed from the boiler after run 5*t* a thin coat of scale was found on the surface of the tube.

The individual coefficients of heat transfer h_L for this series of runs have been plotted in Fig. 13 against the individual temperature difference Δ_L from the outside tube wall to the boiling liquid. It is seen that the coefficients of heat transfer fall fairly well on two separate curves. The upper curve is for the run during which the tube was covered with scale. Thus it seems that the individual coefficients of heat transfer can be reproduced if the surface conditions are controlled, and that the slight roughness on the surface due to a thin layer of scale had a beneficial effect on the liquid-side coefficient of heat transfer.

When small temperature differences were used, the average temperatures on the bottom of the tube were higher than those

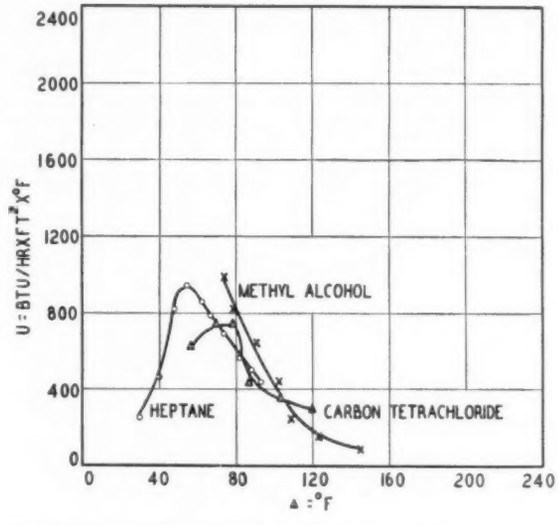


FIG. 12 OVER-ALL COEFFICIENTS FOR VARIOUS LIQUIDS BOILING ON STEAM-HEATED COPPER TUBES, SERIES 1

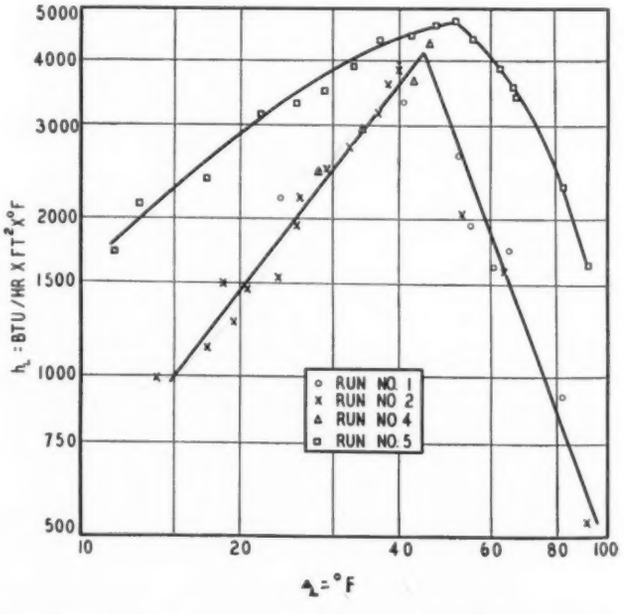


FIG. 13 INDIVIDUAL-FILM COEFFICIENTS FROM TUBE SURFACE TO LIQUID FOR WATER BOILING ON OUTER SURFACE OF A STEAM-HEATED COPPER TUBE, SERIES 3

on the top, but as the rate of heat transfer approached the maximum the situation was reversed, i.e., the top of the tube became vapor-bound before the bottom. When the temperature difference was considerably above the critical, the average temperature of the top of the tube was only slightly above that of the bottom and, since the liquid-side coefficient had dropped so much, the average temperature of the tube was quite close to that of the steam.

Much work remains to be done to clarify the problems of heat transfer to boiling liquids. It should be emphasized that the coefficients obtained in the laboratory apparatus should not be used to design commercial or semiworks-scale apparatus. However, it is felt that the coefficients are comparative, and that the following conclusions can be drawn.

1 The heat flux from steam to liquids boiling at atmospheric pressure was found to go through a maximum for each of the metals and liquids used. For example, the over-all critical temperature difference for water ranged from 115 to 150 F, while for benzene it ranged from 55 to 100 F.

2 When boiling water at atmospheric pressure with clean iron tubes, at over-all temperature differences of not more than 125 F, the over-all coefficients were higher than those for copper or chromium-plated copper with the same temperature differences.

3 With water boiling at atmospheric pressure on copper tubes, the over-all coefficient increased markedly as the surface of the tube became aged.

4 When boiling ethyl acetate, benzene, ethanol, and water, the maximum attainable heat flux was always greater with copper or chromium-plated copper than with aluminum tubes. With one exception, the maximum heat flux with a given liquid was higher with chromium-plated copper than with copper tubes. Iron tubes gave maximum rates of heat flow which were higher than those obtained with any of the other tubes.

5 Using tubes of iron, copper, or chromium-plated copper, the maximum heat flux was least for the nonpolar group, which comprised ethyl acetate, benzene, carbon tetrachloride, and heptane; was intermediate for methanol and ethanol; and was highest for water. See Table 1.

6 Based on the work of series 3 in which surface temperatures were measured while boiling water at atmospheric pressure on a copper tube, the individual coefficient from tube to water increased noticeably after a definitely perceptible scale layer had formed on the outside of the tube. A maximum heat flow of 247,000 Btu per hr per sq ft was obtained when the average temperature of the surface of the tube was 52 F above the boiling point of the liquid, corresponding to an individual coefficient of 4800 Btu per hr per sq ft per deg F difference. The corresponding over-all coefficient was 3200 and the over-all temperature difference was 76 F.

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PERSONALITY: *the* MAIN FACTOR *in* PUBLIC SPEAKING

By S. MARION TUCKER

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SANDERSON AND I had been discussing various devices by which a speaker can arouse and hold the interest of his audience—and I, unfortunately, had been doing most of the talking. All at once he called a halt: "Take care!"

Now, Sanderson, who happens to be a technologist of repute, is a fine speaker. Furthermore, he is remarkably sane and skeptical. So I always listen to him with respect. He knows more about public speaking even in theory than most professionals in the subject, and as to actual practice there are very few who make the theory work as he can. Hence I stopped talking, and waited.

"Take care," said Sanderson. "You have talked a lot about your various devices for arousing and holding the interest of an audience. I'm glad to see that you have at least sense enough not to lay down any 'rules' or to say that any one of your nice little tricks will always work. And I grant that what you say is fairly practical. After all, these devices have been pretty well tested for ages. Even you and I often practice them, consciously or unconsciously. But you forget the most important factor in holding interest. It can work either positively or negatively. It can attract an audience or antagonize it. You have left the main thing unsaid."

"Well, what is it," I demanded, somewhat annoyed to be coolly suppressed in this rather superior fashion.

"The personality of the speaker, of course," Sanderson replied. "You know that as well as I do. And just as soon as you say this, nobody will listen to you any more. You see, 'personality' is so intangible, so vague. You can't reduce it to a rule or formula. And you know how people love rules and

Seventh, in a series of articles on the presentation of technical papers.

formulas. They save thinking. People love to be told what to do. Well, that's all right when science is in question. But it's almost impossible to get sheer human nature into rules and formulas. That's just where so many of us scientists go wrong. An audience is just plain human, that's all. So it likes to be spoken to by a plain human being and not by a machine. Take that or leave it—you can't help it. This means that those interest devices, no matter how good they are, won't work unless the speaker has an appealing personality. Without that, nothing."

"But," I retorted, "surely everybody knows this. We all feel it. We know that one man can do anything with an audience just because his personality happens to suit it, and that another man, maybe much finer and abler, doesn't please that audience a bit. I didn't say this before because I thought it was taken for granted."

"Not a bit of it," said Sanderson. "It's not taken for granted at all—by most people. They'll swallow your 'rules' greedily. They'll study your formulas—if you give them any. And they'll miss the whole point—the only thing that fundamentally matters. They grasp at the shadow; they lose the substance."

"You know," he went on, "that if a speaker's personality pleases his hearers, he can make such bad technical breaks in his speech that he ought to be put in jail, and yet get away with it. And, on the other hand, a speaker whose personality does not 'get across' can practice all the arts and graces and yet antagonize everybody."

"There's our friend Capton, for instance," Sanderson continued. "He always talks sense. He uses good language. But he's as cold as an iceberg. He looks stern, because his facial muscles are rigidly set. His eyes are cold. His voice has a temperature far below zero. Yet the man isn't really like that underneath. He has an icy reserve on the outside, but he's warm and kind deep down inside of him. But how can an audience know this? The audience sees only the outside. He never lets it get beneath the ice."

Now that Sanderson had taken over the conversation, and got his steam up, he wouldn't be sidetracked. Evidently, he had thought about this "personality business." He had another example:

"Then there is Heverling. His personality is altogether different from Capton's, but it's even less attractive. He looks so damnably self-satisfied. You know how he rolls out all that pompous stuff of his as if it came straight from God. He's incased in an impenetrable armor of self-conceit [Sanderson, being human, likes to show off his fine language sometimes]. He never suspects that his audience loathes his personality. Even if he deliberately tried to please, I doubt if he could do it. He simply doesn't know how to humanize himself. He would be like an elephant trying to waltz. But Heverling in private and Heverling in public are one and the same person. He's *always* offensive. Capton, poor fellow, shows only the less likable part of himself, hardly shows his true self at all. Heverling shows all of himself all the time . . . . . Why don't you say something?"

"I haven't had a chance," I meekly responded. "But I was thinking about Harkins. You remember his presidential address at the Society—how labored it was and how cold his manner was? I guess he was too much impressed by the occasion and his part in it. He felt that he had to rise to that occasion and seem very dignified to the audience. What he said was all right, but he had written it out in a formal style—and he read it. He read it very well, because he had practiced the reading. He told me so. And he looked fine, too, on the platform. He stood straight, and he was dignified. But he did seem so impersonal and cool and rigid, so far away from us. He was just like a lot of us who get so painfully conscious of ourselves when we have to make formal speeches on dignified occasions."

"But here's the point," I continued. "It's a very illuminating and suggestive one. Several times Harkins disregarded his manuscript and looked directly at us. Then he spoke *impromptu*, made it up at the moment. Whenever he did this, he smiled. Well, you never saw such a change come over a man's face and manner. He has a very winning smile. It alters his whole expression. His eyes light up, and his voice grows warm. Whenever he did that, he seemed like a different man—and how much more attractive he was! His personality became utterly different. You could actually sense that the audience felt a little thrill of response whenever he let himself go. But after that little byplay, he'd freeze up again. Too bad."

"Harkins," remarked Sanderson, "is just like hundreds of other fine men, perhaps really likable men, too, who seem to freeze on the platform. Perhaps they get self-conscious. Maybe they believe that the occasion calls for dignity and impressiveness. I think that scientists and technologists suffer from this more than other speakers. Perhaps it's the kind of subjects that they usually talk about. Whatever the reason, they are often heavy and dull where they might just as well be light and interesting. They freeze the audience where they might just as well warm it. Most men have something human and appealing in them, if it's allowed to come out. It isn't their *inside* but their *outside* that's to blame. If a speaker just hasn't the kind of personality that wins an audience, he had better set out to create one, or stay off the platform."

"But what do you want the man to *do*?" I demanded, "turn cartwheels and somersaults in order to be animated? Grin? Play elocutionary tricks with his voice?"

"I mean nothing of the kind—and you know it," retorted Sanderson. "And yet . . . you remember Billy Sunday, the 'revivalist'? He had been an athlete, and he cavorted all over the platform as he preached. Well, no doubt he overdid it, but at least he was expressive. He had a personality that appealed to hundreds of thousands. He got a response. Of course a very little of that kind of thing goes a long way, and it offends dignified people. But a bit of that man's flexibility of body and facial expression and voice wouldn't hurt some of our frozen speakers. They might learn something from Billy Sunday's technique. You'd better be excessively animated than excessively rigid."

"Yes, you're right," I answered. "And a speaker can even insult his audience, if he does it in the right way, and yet attract it. There's George Bernard Shaw. He isn't handsome and he isn't graceful, though he has a beautiful voice. Well, Shaw knows human nature and studies his audience, so he gets away with anything. It's just because he has a personality that establishes communication between him and anybody he talks with."

"That's true," said Sanderson. "And you know Graffing? He's little, he doesn't look like much, he dresses badly, and he has a weak voice. He's awkward, too. But Graffing has something, all the same, that holds the crowd. He can say anything and make them listen to it—and like it, too. Well, that's personality. We have all seen it and heard it a thousand times, and every time it's something different. ***But it's always human.*** It always shows feeling. That's all I can say. Don't ask me for definitions, or for rules or formulas. You won't get 'em in this case. Go to the psychologist and ask ***him***. Perhaps he can explain the matter. But I doubt it. I hope it will stay indefinable and unexplained."

Engineering Factors Involved in ORCHARD HEATING

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ALMOST one third of the entire California citrus acreage now has heater equipment, a second third does not suffer frost damage often enough to warrant heating systems, and in the other third the need for heaters is marginal. In January, 1937, about 85,000 acres were heated to prevent frost damage. Almost four million orchard heaters are in service. Each one must be individually lighted and regulated, and all but a few of the tens of thousands must be individually filled. About two million barrels of fuel oil and 17,000 tons of solid fuel (coal, coke, wood, and rubber tires) were burned during approximately 15 nights from Jan. 5 to 27, 1937. The available supply of coal or solid fuel was adequate for only a small acreage. The gas-oil consumed in these three weeks drained all southwestern storage, emptied out-bound tankers, and required large emergency shipments from distant refineries. The total quantity burned in three weeks was about 3 per cent of the whole U. S. annual refinery output of this grade of fuel. The local transportation systems were inadequate and a few ranch operators became so desperate that some oil trucks never reached their intended destinations. Some growers lost their crops the last night of the freeze. Although in 1937 there was a shortage in fuel oil of the desired 27+ deg A.P.I. gravity Diesel grade, oil is the only fuel which can be considered for the general practice of orchard heating. Because the refiners cannot carry adequate stocks, many growers have installed ranch storage ranging in capacity from 350 to 3000 gal per heated acre. This permits purchasing fuel at seasonal low prices but introduces problems of evaporation loss, leakage which may injure trees, and deterioration of tanks.

The direct benefits of emergency heating of citrus orchards are indicated in the report of one grower who spent $1000 for wood and saved a $5000 lemon crop. The general advantage of heating to the entire citrus industry can be visualized in the 35,000 cars of fruit saved at a time when about 30,000 other cars originated in unfrosted areas, and probably 35,000 carloads were lost in frosted areas owing to lack of heating equipment or inadequate heating.

Considerable tree damage also was prevented, hence the financial saving of the 1937 orchard heating was no doubt more than $60,000,000. Against this amount there was a direct heating cost of about $7,000,000 and an indeterminable smoke damage, estimated at $2,000,000 for merchandise and from $4,000,000 to $5,000,000 damage to homes in Los Angeles metropolitan area.[1] In contrast to the exceptional freeze of January, 1937, the winter season of 1937–1938 was so warm that there was no general firing. Only on one morning, March 30, 1938, was there scattered firing, when lemons needed frost protection six weeks after the regular Weather Bureau frost warnings had been discontinued. This year-to-year variability in use of heater equipment indicates one phase of the economic problem.

Probably orchards can be heated more efficiently and more effectively than at present, although the burning time is now closely controlled both at starting and ending to conserve fuel. It was partly in hope of developing different methods of orchard heating that the current research project was established to investigate new and present methods of orchard heating and to obtain a more complete understanding of all the phenomena involved. The heater studies and the controlled laboratory investigations are conducted in the agricultural-engineering research laboratory, University Farm, at Davis. The field observations of orchard conditions and outdoor heating characteristics are made during the winter at the Citrus Experiment Station at Riverside. (See Fig. 1.)

OUTDOOR HEATING PRACTICE

The rate of oil consumption in citrus orchards as indicated by a field survey of the current practice of about 400 growers varies greatly with different weather conditions, ranging from 10 to 125 gal per acre-hour. In terms of heat, a firing rate of 25 gal gives about 25 × 140,000 or 3,500,000 Btu per acre-hour. This energy is used for producing a rather small modification of outdoor temperature, namely, raising the night air temperature near the ground a maximum of about 10 F. If this 10 F rise is

[1] From a statement of H. C. Legg of the Los Angeles County Board of Supervisors at a meeting in Covina, Feb. 5, 1937.

Courtesy of California Citrograph

FIG. 1 VIEW SOUTH FROM THE ORCHARD-HEATING RESEARCH FIELD HOUSE SHOWING SIZE OF TREES, TYPICAL HEATER DISTRIBUTION, GROUND CONDITIONS, AND THERMOCOUPLE NETWORK

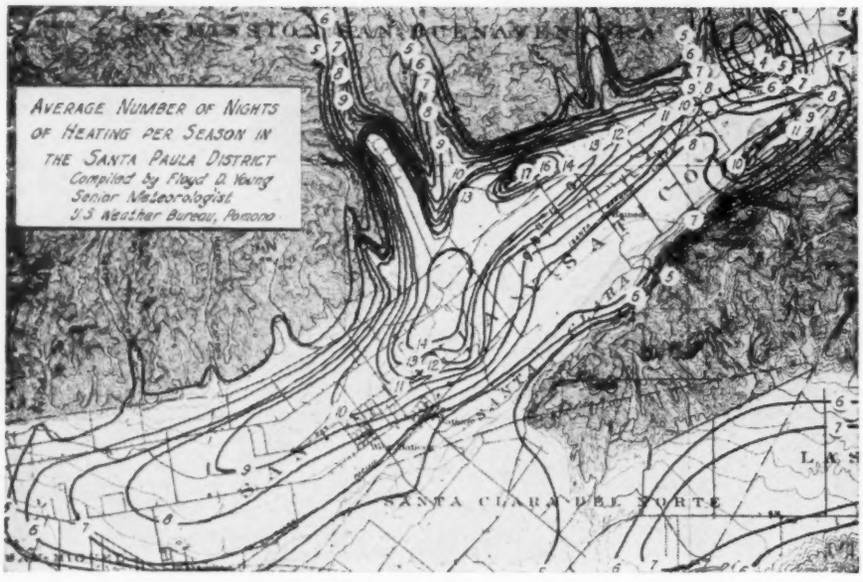
AVERAGE NUMBER OF NIGHTS
OF HEATING PER SEASON IN
THE SANTA PAULA DISTRICT
Compiled by Floyd D. Young
Senior Meteorologist
U.S. Weather Bureau, Pomona

FIG. 2 EFFECT OF TOPOGRAPHY AND DRIFT OF COLD AIR ON NEED FOR ORCHARD HEATING
(The figures indicate the average number of nights of orchard heating required per season in different areas in the district.)

to be produced in quiet air, only one twentieth of the heating rate cited would be required to warm an air layer 20 ft thick (neglecting the sky radiation loss). But almost always there is some air drift, roughly 2 to 3 mph, which is equivalent to about 50 air changes per hour for single square acres. This makes it nearly impossible to warm the air of small isolated tracts. However, in the so-called "mass heating" of large areas the border effect diminishes and the main requirement is to supply heat to counteract the normal cooling of the atmosphere.

Nocturnal ground radiation on frost nights to the cold sky amounts to from 25 to 40 Btu per sq ft-hr, or, say, 1,500,000 Btu per acre-hour—roughly 40 per cent of the 25-gal-rate heater output. Heat lost from the warmed air upward by eddy diffusion is restricted by the usual temperature inversion of the atmosphere near the ground. The diluted products of combustion, after rising 30 ft, are only a few degrees warmer than the original air, and an equally warm temperature is usually reached within 60 ft of the ground. Above this level there are usually several hundred feet of warm air.

The orchard-heating problem is thus naturally divided into two phases (1) central-area heating to counteract direct sky-radiation losses, and (2) border heating on the upwind side to warm all the incoming air to a safe temperature and to a height at which the air is naturally at this temperature. Unless counteracted by a low "ceiling," central-area heating is most difficult in quiet air when stack gases rise vertically and diffuse so slowly that direct radiation heating to the trees and ground is the only effective means for frost protection. Strong air movement associated with "freezes" requires special heater grouping. Present border practice often calls for two rows of heaters spaced equivalent to one every ten feet of frontage. This provision is not adequate to warm the entire cold stratum of the oncoming air, but since the first row of trees is directly protected, the full-depth air warming is accomplished by subsequent interior rows of heaters.

FUNDAMENTAL CAUSES OF FROST

In the citrus districts, naturally located in areas not subject to subfreezing temperatures in the daytime, the *frost* damage is due primarily to the nocturnal loss of heat by radiation to the cold sky. The air itself does not lose much heat by radiation, but becomes chilled because of contact with the cold ground or other exposed surfaces, principally plant leaves, which radiate energy to the sky. Even in the cases of so-called *freezes*, when a cold air mass of polar origin invades the citrus districts, it is the regional chilling of this air at night which is most damaging. The cooled air is more dense than the warmer air above and remains close to the ground, getting colder as long as the surface temperature of the earth continues to fall. Topographical air drainage produces "cold spots," and there is large variation in heating requirements of different localities, well indicated on the map of the Santa Paula district, California, Fig. 2.

One of the primary factors in the formation of a frost hazard is the rate of radiation of energy from the ground surface to the cold sky. The outgoing terrestrial radiation is largely absorbed by the water-vapor content of the atmosphere and hence the net nocturnal radiation from the surface of the earth varies greatly with the concentration of water vapor in the lower levels of the atmosphere. The relatively dry air during the exceptional freeze of January 22, 1937, originating in polar regions, had a water-vapor content equivalent to a layer of water about 6 mm thick; and at 6:00 a.m. the maximum air temperature was 34 deg, at 800 ft above sea level over San Diego. During light radiation frosts in January and February, 1938, the air mass over San Diego usually contained about 17 mm precipitable water and the maximum temperature ranged from 48 to 67 F.

The nocturnal radiation exchange from the ground to the sky is highly selective with wave length. There is a nearly transparent band in the atmospheric water vapor at 10 microns, which is at the peak of outgoing terrestrial radiation, bordered with strong absorption bands below a wave length of 8 microns and above 14 microns. Fig. 3 shows an idealized spectral distribution of nocturnal radiation exchange due to water vapor in the lower levels of the atmosphere. Most of the heat radiated to the sky comes from the ground and hence the drop in air temperature will vary with the wetness of the soil.

A full cloud layer acts as a screen counteracting the nocturnal terrestrial radiation, but radiation cooling proceeds even though there are high cirrus clouds. Calm clear winter nights are most favorable for the pronounced cooling of ground surface because the lowest levels of air, cooled mostly by contact with the cold ground, are not mixed with the warmer air above. The air 40 feet above the ground is often warmer than at the 5-foot level, by more than 10 F.

Fig. 4 shows three examples of vertical air temperatures found with a captive balloon and two corresponding aerological observations taken at Burbank 60 miles east of Riverside and at San Diego 90 miles south, which indicate the general air-strata temperatures likely to be found over the Riverside tract. The observations of Jan. 27, 1938, show a strong temperature inversion to 125 ft above the ground. It is to be noted that lower-air temperatures are not steady, although the balloon was upwind from the area being heated. At 50 ft, a $5\frac{1}{2}$-F change was found within 15 min. The air temperature above 125 ft is

apparently nearly constant at 63 F up to 2000 ft and in the next 2000 the temperature drops only about 6 F. The balloon observations for Feb. 13 (when aerological soundings at Burbank and San Diego were not reported) show a rather poor temperature inversion, but are interesting as a demonstration of the effect of artificial heating below 50 ft. The records of Feb. 26 show excessive low-level inversion and constant 58-F temperature from 150 to 1000 ft, above which there is a temperature drop of about 14 F in the next 3000 ft. The progressive cooling toward dawn of the lower air is clearly shown in all three examples.

ORCHARD-HEATING EXPERIMENTS IN 1938

The actual field measurement of orchard-heating effects proved unexpectedly difficult. Temperature measurements were made with 150 iron-constantan thermocouples. The responses were recorded by two single curve-drawing photoelectric potentiometers with automatic switching, allowing $7^1/_2$ sec per couple. The temperature variation of any one couple was tabulated later from the strip chart. The quickest round-trip recording of one 25-point switch required $3^1/_8$ min, which was used with one potentiometer connected only to thermocouples located outside the test tract for controls. Even this time interval was too long to indicate truly the succession of colder and warmer bodies of air which drifted across the exposed couples.

The thermocouple junctions were butt-silver-soldered 24-gage wire and were bare for $^3/_4$ in. on each side of the junction to provide a relatively large air-contact surface. These small-wire couples were not shielded because it was found that their response to radiant energy from the heaters was negligible, although couples of 16–18 gage showed 3 to 4 F change when exposed 6 ft from orchard heaters. Although the rapid fluctuations of air temperature are of interest, a smoothed record would be more useful; so it is now planned to add heat capacity and shielding to make the thermocouple response more representative of the *average* temperature for a time interval comparable to that between periodic readings. The fastest round-trip recording of the heated-area thermocouples was $9^3/_8$ min, covering three 25-point switches with a $7^1/_2$-sec interval per couple. This interval is plainly too long to catch the effect of a gust of wind which can come in crossdrift, rising to a velocity of $3^1/_2$ mph, and vanish within 5 min. Such gusts often upset part of the test tract readings without reaching the control thermocouples which necessarily are a few hundred feet away.

The raising of tree-center temperatures by means of artificial heat is clearly shown by the shaded area in Fig. 5. The air temperatures above trees at 15 ft show the most response to artificial heat because under the test conditions the products of combustion from the heaters passed above the treetops and drifted away in a layer roughly between 10 and 30 ft above the ground. The observations plotted in Fig. 5 were made while there was a large temperature inversion, shown at the right in Fig. 4.

The temperature fluctuation at the 60-ft level might be noted. This shows some sudden changes of 5 F within the observation cycle of $3^1/_8$ min, which seem to be due more to change of direction of the air drift than to mixing or change of temperature within a particular stream of air. In other words, small changes in temperature are to be expected in air drifting along one general path, but larger changes indicate arrival of air from a path having different cooling characteristics. The mixing effect of stronger wind can be seen in Fig. 5 at 2:30 a.m. when the rise in wind velocity to nearly 6 mph caused the lowering of the 60-ft temperature and raising of all near-ground temperatures.

Experimental comparison of one kind of heater with another or quantitative measurement of the effect of different heater-location patterns within an orchard were not obtained. Such comparisons might be possible with the steadier air conditions associated with colder frosts. Heaters located one per tree, but three rows apart, failed to warm the center row of trees when the air drift happened to come straight down the rows; but for large-area heating and cross-row drift such a location pattern has been successful in practice.

DIFFERENCES IN HEAT OUTPUT OF DIFFERENT TYPES OF HEATERS

There are demonstrable differences in the excess air taken into some heaters which point to different heating effects of the products of combustion. The output of radiant energy differs markedly for different types of heaters. Roughly 20 to 40 per cent of the heat of combustion is discharged in net radiant-energy exchange in different distribution patterns.

The radiant-energy emission pattern from a "lazy-flame"

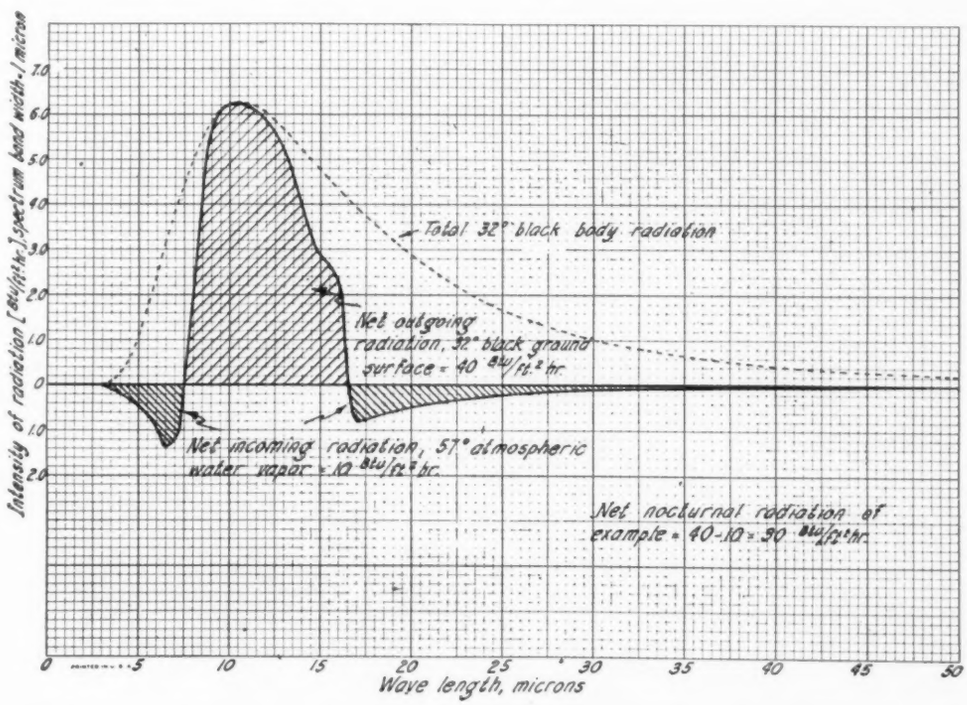

FIG. 3 EXAMPLE OF SPECTRAL DISTRIBUTION OF NOCTURNAL RADIATION EXCHANGE BETWEEN THE GROUND, COLD SKY, AND WATER VAPOR IN THE LOWER LEVELS OF THE ATMOSPHERE

(Temperatures in degrees Fahrenheit.)

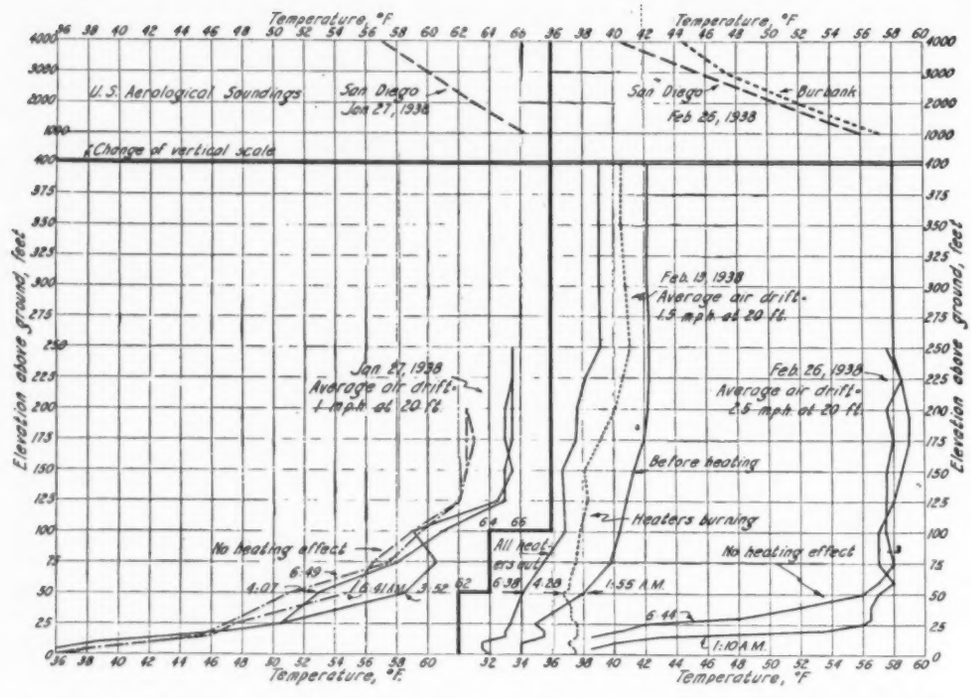

FIG. 4 EARLY-MORNING AIR TEMPERATURES AT DIFFERENT HEIGHTS ABOVE THE GROUND, AS OBSERVED BY BALLOON AND AEROLOGICAL SOUNDINGS JAN. 27, FEB. 13, AND FEB. 26, 1938

heater, where most of the combustion occurs above a short stack, is shown on the left side of Fig. 6. At the right is shown the emission pattern for an inverted air-jet oil burner. The large "lazy" flame is rather translucent in comparison with the smaller bright-yellow torch flame. In both cases inside figures show the measured radiant-energy output (not at equal burning rates) and the outside figures indicate the percentage of total heat of combustion, discharged as radiant energy at a given angle to complete spherical surface segments with band widths of 15 deg. These spherical band figures do not parallel the vertical-plane intensity patterns because the spherical equatorial area is so much greater than the polar. This spherical surface limitation to energy discharged upward is most obvious in the case of the lazy-flame heater.

The net intensity of 102 Btu per sq ft-hr (at 7.65 ft, 50 F) discharges only one tenth as much energy vertically over an angle of 15 deg as does 33 Btu per sq ft-hr horizontally. All the radiation discharged to the sky is practically a total loss, and only that striking the trees and ground is immediately effective in frost protection.

In an ordinary orange grove with trees on centers 20 by 24 ft and 11 ft high, and the heaters in the center of the row spaces, the interception angle from the heater to the nearest treetop is about 30 deg from the horizontal. The angle to the treetop in the next row is only about 13 deg. The row spaces are open horizontally in four directions. Hence the interception bands for this relatively open grove might be assumed to include only the ones centered 15 deg above horizontal and below this. Such separate heater tests show that the lazy-flame might lose half its radiant heat to the sky, or about 14 per cent of the total heat of combustion. The inverted air-jet burner with a more favorable emission pattern would correspondingly lose less than a third of its radiant heat to the sky, but this air-jet burner, discharging more of its total heat as radiation, would still lose about 13 per cent of its total energy to the sky. This result indicates a possibility for better shielding; but any additional cost, although small per unit, means a large increase in capital investment per acre of 50 to 100 heaters which have a very low use-factor.

There are well over 3,500,000 oil-burning heaters in citrus orchards. Most are of the 9-gal bowl or so-called "distilling" type in which there is a small flame on the surface of the oil. This flame virtually burns air in an atmosphere of fuel vapor and is separate from the main combustion. Fuel vapor can be generated by radiation heating without a pilot flame, but unstable operation usually results. These sheet-iron heaters are remarkably efficient; new heaters[2] sell at from $2 to $4.50 each

[2] "The Smokiness of Oil Burning Orchard Heaters," by Warren R. Schoonover and F. A. Brooks, College of Agriculture, Bul. 536, 1932, p. 67, University of California, Berkeley, Calif.

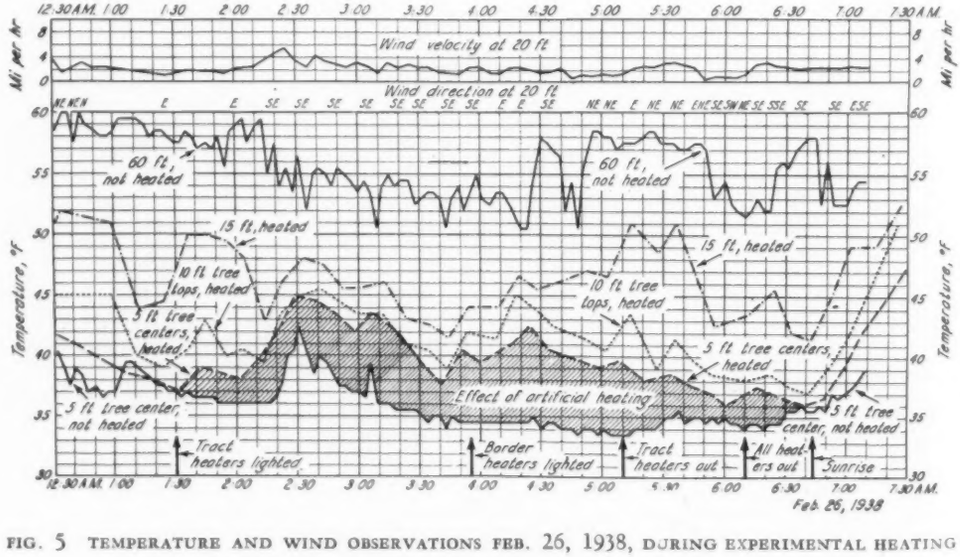

FIG. 5 TEMPERATURE AND WIND OBSERVATIONS FEB. 26, 1938, DURING EXPERIMENTAL HEATING OF A ONE-ACRE TRACT OF EIGHT-YEAR-OLD ORANGE TREES

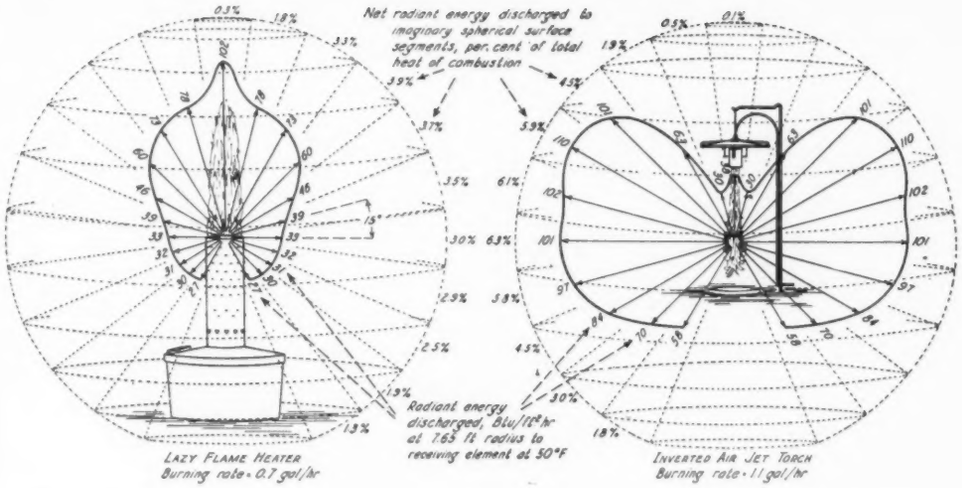
Net radiant energy discharged to imaginary spherical surface segments, per cent of total heat of combustion
Radiant energy discharged, Btu/ft²hr at 165 ft radius to receiving element at 30°F
LAZY FLAME HEATER
Burning rate = 0.7 gal/hr
INVERTED AIR JET TORCH
Burning rate = 1.1 gal/hr

FIG. 6 PERCENTAGE OF TOTAL HEAT OF COMBUSTION DISCHARGED AS RADIANT ENERGY TO SPHERICAL SURFACE SEGMENTS OF 15 DEG BAND WIDTH BY A LAZY-FLAME HEATER (LEFT) AND INVERTED AIR-JET TORCH (RIGHT)

and do not produce visible smoke when properly operated. Unfortunately, most of the heaters in use were designed as smudge pots, at a time when smoke was considered desirable, so the smudge nuisance is now acute whenever there is a succession of cold nights.

One of the serious troubles with bowl-type heaters is the accumulation of soot and other carbon deposits within the bowl. Sometimes a fluffy soot will completely fill the bowl and prevent operation of the heater. Usually, there is a heavier carbon deposit which builds up in the bottom about 1 in. deep for each 20 to 30 gal of fuel burned. It has long been recognized that the introduction of steam in the bowl would decrease the smoke and carbon residue. The use of water in subfreezing temperatures is not practical, so A. S. Leonard (while a staff member of the California Agricultural Experiment Station) developed an alternative method which consists of returning the nearly inert stack gases into the bowl, as is illustrated in Fig. 7. This design has been relatively successful in minimizing soot.

The whole question of orchard-heater fuel-oil specification is open at present, because the grower has no simple way of determining combustion quality and the large oil producers cannot afford to establish a distinct refinery practice for the erratic demand for orchard-heating fuel. Since carbon residue is the main operative difficulty in orchard heaters (except the obvious need for low pour point), some test methods were investigated for determining the carbon-forming tendency of various gas-oils under free-surface burning, as distinct from the closed, externally heated Conradson test. A reasonable correlation was obtained between an open-crucible burning test and the field reports of heater difficulties, so this new carbon test method is now being studied by the oil industry.

ORCHARD-HEATING OPERATIONS

In lemon groves the heaters are distributed throughout the orchard often one per tree, or nearly 100 per acre. For oranges, which withstand colder temperatures, about half as many are used. In all cases the labor problem of distributing the fuel in the field, lighting, regulating, and cleaning, is acute, because the demand is simultaneous over large areas, requires night work in subfreezing weather, and the jobs are very dirty and arduous. The ground is often muddy when refilling must be done, and usually the ground is furrowed for irrigation and bearing a cover crop. Trucking over wet ground injures the soil structure, so tank-wagon driveways are restricted and most filling of heaters is done by hand with 5-gal buckets.

During the 1937 freeze the long hours of burning often required refilling at night when the heaters were burning, and because the men had almost no rest night or day, the manual filling operations practically failed on the third successive day. Fortunately, night temperature rose somewhat then and allowed some resting, but there were repetitions of such periods of severe two- or three-night frosts. These operating troubles in 1937 led to the more extensive use of pipe-line distribution of oil within the orchard both direct to heaters and as hydrant lines to permit filling by hose.

The ordinary heating-equipment investment, new, amounts to about $200 to $400 per acre for oranges and lemons, respectively. The hydrant pipe-line system would add about another $100 per acre, so there is now some interest in central heating systems if these can be had within $500 per acre. The two small installations of piped hot-air systems are adjacent to or surrounded by areas heated by the usual bowl-type heaters, so no conclusive field demonstrations have been possible. The test of undertree liberation of hot air carried out at Riverside in 1938 was disappointing in that the general air drift carried the hot air out of the tree in a very narrow path so only a small fraction of the tree was protected under those atmospheric conditions. The unexpected slowness of the dispersion of warmth within a tree either by radiation or by eddy diffusion was not encouraging for the use of undertree heat.

This research project financed at the start by a special grant from the Fruit Growers Supply Company and extended by special legislative grant, is being carried on by the Agricultural Engineering Division of the University of California, H. B. Walker chairman and in active charge of this project. Full-time project members of the division are R. L. Kepner, C. Lorenzen, C. E. Barbee, and the author. Part-time project members are L. M. K. Boelter, professor of mechanical engineering, University of California, Berkeley, and A. L. Coons, University Farm Engineer, Davis, Calif.

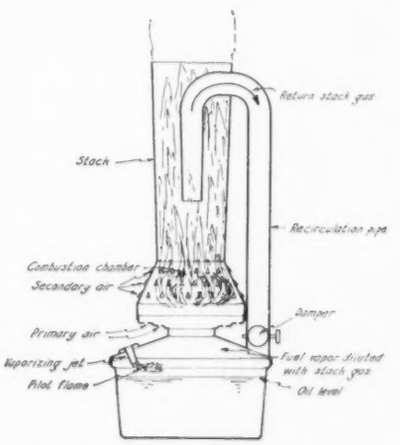

FIG. 7 DIAGRAM OF LEONARD RETURN-STACK-GAS HEATER DESIGNED TO MINIMIZE CARBON FORMATION IN THE BOWL

The History of RUBBER *as an* ENGINEERING MATERIAL

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UNTIL RECENT years the rubber parts of all rubber articles used in connection with machinery have neither carried sizable loads nor transmitted power. Although uncounted tons of ore, coal, and coke have been transported upon conveyor belts, and although belts and automobile tires transmit power and carry loads, the purpose of their rubber parts is to hold together the strong plies of cotton fabric and to protect them from abrasive wear.

Then, too, the softness of rubber compositions relative to metals and their ability to conform to the irregular surface shapes of structures led to their early and continued use as valve disks and pipe-joint gaskets for water, steam, and air lines. The electrical properties of rubber coupled with its flexibility gave rise to its extended application as wire insulation. Rubber compositions of the correct sort are highly resistant to acids and many other chemicals, hence they can be used as linings for tanks in which chemical processing is accomplished. It is notable, however, that the rubber parts, as differentiated from the metal or fabric parts of all these and many other so-called rubber articles, are relatively thin and carry no load.

In this paper no exposition is undertaken of the physics of rubber in relation to energy absorption or to the design of blocks and shapes for that object. Reference is made to a few pertinent analyses already published. Hirshfeld and Piron (1)[1] described rubber with reference to its use as springs for streetcars. Macbeth (2) discussed rubber in automobiles with particular attention to wheel suspension. Hahn (3) describes a particular type of support for heavy machinery. For data on the physics of rubber one should refer to the excellent chapter by Vogt (4) in a recent book.

Therefore, this discussion is limited to some of the high points of the history of rubber compounding with the especial object of showing why it has been possible only within recent years to use rubber as an engineering material, and why today it is possible to manufacture and use rubber successfully in a structure as a component part upon which the essential performance depends. These parts may be of any desired dimensions, either large or small, and are of especial value in supporting vibrating and shock loads because of the inherent peculiar ability of vulcanized rubber to absorb energy.

CHEMISTRY OF RUBBER MIXTURE

From the nature of the case this discussion must center around the chemistry of the rubber mixture, and therefore some of the fundamentals are briefly reviewed.

Rubber is a vegetable product that exists in the form of extremely fine particles dispersed in an aqueous medium in veins of the bark of certain trees which grow in the tropics. When these trees are cut, or according to a well-understood system the bark is tapped scientifically, a thin milky fluid exudes. This is called latex. It runs into cups attached to the tree, is collected, and is taken to a central factory where the rubber content is coagulated by means of a small percentage of acetic acid. After this coagulated product is washed and dried it becomes the solid crude rubber which is the basic ingredient of the vast majority of rubber articles.

During recent years considerable quantities of liquid latex have been shipped from the Far East to this and other manufacturing countries either in its natural concentration of from 36 to 38 per cent total solids, or in one in which the rubber content has been brought up to 60 per cent or more. A new science and art of manufacturing rubber articles directly from liquid latex has developed during the last ten years. We are not concerned with these processes in engineering, because latex, as distinct from solid crude rubber as a raw material, has value primarily in the manufacture of small articles, and those which have high extensibility. This state of the art may not be permanent, however.

Up to the year 1839 the only rubber known was crude rubber, which possessed the unfortunate properties of solidifying to a leather-like product when its temperature fell to freezing, becoming even brittle at below-zero temperatures, and softening to a sticky mass in hot weather. Crude rubber has high plastic flow and a softening point or range but little above that of atmospheric temperature. Naturally these properties restricted the use of this material. Charles Goodyear in 1839 discovered that when a mixture of rubber and sulphur was heated its physical properties were altered. This process was called vulcanization, and that year marks the beginning of the rubber industry. Vulcanized rubber is nonthermoplastic at temperatures well above the highest atmospheric and remains elastic down nearly to —70 C.

However, the Goodyear type of vulcanized rubber compound was an irregular product. Crude rubber varied according to its source, and it was all obtained from forest trees of several species. The time required to vulcanize a mixture of rubber and sulphur alone was long, about two to five hours. Certain substances were known which would increase the rate of vulcanization, but speeds were difficult to control and physical properties could not be exactly reproduced. Different lots or batches of vulcanized rubber were apt to vary due to the difficulty of obtaining the proper cure, or vulcanization. We now know that some of these troubles were due to variability of crude rubber, to the nature of the various ingredients mixed into it, and also to the lack of accurate control of steam used to supply heat. It was natural, therefore, that the majority of rubber articles were those which could be useful when the rubber parts of them were relatively thin in section, when physical tolerances were large, and when rubber was supported by cotton fabric.

During the period 1839 to 1906, coincidental with the de-

[1] Numbers in parentheses refer to the Bibliography.

Contributed by the Process Industries Division for presentation at the Fall Meeting, Providence, R. I., Oct. 5–7, 1938, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

mand from industry, there was a steady development in the use of vulcanized rubber for conveyor belts with a surface to resist abrasion, hose to carry water and air, belts for power transmission, gaskets, tires, shoes, surgical goods, wire insulation, and similar articles. The solid tire is about the only one of a long list of rubber products, the dimensions of which were comfortably large, and even these solid tires, cured under the most careful conditions then known, were not identical from surface to center in degree of vulcanization.

Of the several reasons for these irregularities the chief was the type of substance used to speed the combination of sulphur and rubber. It is now common knowledge that this combination is chemical and not simply a physical adsorption between these two substances. Certain catalysts or accelerators were well known, of which lead oxide, magnesium oxide, and calcium hydroxide were most usual. It was necessary to use relatively high proportions (from 5 to 20 per cent) of these materials and from 10 to $16^2/_3$ per cent of sulphur to obtain a satisfactory product, which meant in those days a strong, snappy vulcanized product.

During the first ten years of the present century the results of two pioneering efforts became known and available to the rubber industry. The first of these was the development of the rubber plantation in the Far East, which originated with Sir Henry Wickham, who started the enterprise on the island of Ceylon in 1876. As has been stated wild forest trees constituted the whole source of supply of crude rubber. There were many botanical species and many qualities of crude rubber from many countries. Wickham wisely chose his seeds from the one best strain of the species *Hevea brasiliensis* of the upper Amazon River valley. Because of his vision and the efforts of the English and Dutch planters, some 98 per cent of crude rubber now used throughout the world comes from well-regulated plantations where the trees are cared for, and the rubber latex is collected, coagulated, processed, and shipped with adequate scientific supervision. Therefore, even though crude rubber is of vegetable origin and shows some variations, nevertheless a standard, reliable, uniform product, capable of reproduction in any desired tonnage, is available.

ORGANIC ACCELERATORS

The physical irregularities of vulcanized rubber have been conquered by a series of extensive chemical investigations which began in 1906. In that year George Oenslager of Akron, Ohio, discovered that when small quantities of aniline oil, in the order of 1 per cent in terms of rubber, were mixed with the crude rubber and sulphur together with some zinc oxide, the vulcanization took place in much shorter periods of time. Not only that, but smaller proportions of sulphur were required to yield maximum physical properties. What was equally significant in those days, low grades of crude rubber gave much higher tensile-strength values than when vulcanized by aid of litharge. Because this new material was organic in character, the use of the term organic accelerator naturally followed.

Following this discovery and the practical application of it, a large number of researches were undertaken and literally hundreds of organic accelerators were found, each of which possesses its own peculiar effect upon the time and temperature of vulcanization, and also upon the physical properties of the vulcanized rubber mixture.

Of especial pertinence to the use of rubber in thick blocks as an engineering material is the characteristic of certain organic accelerators which when mixed with rubber and not too high a proportion of sulphur, permit vulcanization at a given temperature over long periods of time without overcure. For example, two compounds *A* and *B* are mixed of the same materials and proportions except that they contain different accelerators. Sheets of each of these are vulcanized in a press at 287 F for periods ranging from ten to ninety minutes. Test pieces are cut and broken in the testing machine and a curve of tensile strength versus time of cure is obtained for each compound.

The curve of compound *A* shows a rapid rise in tensile strength with time, a sharp peak, and a rapid decline. Compound *B* gives a tensile-strength curve that rises and remains at a maximum over nearly the whole ninety minutes. In other words it has a flat curing curve. Each accelerator gives to such a type of compound its own characteristic curing curve. Similar curves can be drawn to show the effect at several temperatures, when the time of cure remains constant.

The development of organic accelerators which give a flat curing curve for a compound has great significance in the field of engineering, because it makes it possible to vulcanize thick masses of rubber without risk of overcuring the outside portions to cure the inside portions properly. In other words, when a temperature is selected which is in harmony with the characteristics of a desirable accelerator then thick masses of rubber can be vulcanized with the certainty of uniform physical properties throughout the product. Because of the low thermal conductivity of rubber and the fact that the vulcanization reaction is exothermic, it is customary, when a large volume is vulcanized, to raise and lower the temperature gradually over a long period of time.

ANTIOXIDANTS

The older rubber compositions in which only inorganic materials were used possessed not only the irregularities mentioned, but also one further trouble, against which the rubber manufacturer found it necessary to be constantly on the alert. It was not unusual for rubber products to become hard, brittle, and weak after but a few months. This decay is now known to be an oxidation reaction.

About 1918 there began to be used in the rubber industry certain organic compositions which possessed the property of inhibiting the oxidation of vulcanized rubber. Apparently it is not definitely known who was responsible for the first use of these antioxidants. A large number of such substances are in customary use and the problem of rapid aging of vulcanized rubber is conquered. There is only one exception to be made to this statement. It is not yet known how to protect vulcanized rubber from the deteriorating action of sunlight, although a properly mixed composition will remain in good condition in the sun for much longer periods of time than in the earlier days of twenty or more years ago.

From the beginning of the industry dry powders have been used in rubber mixtures to stiffen or to reinforce the product. About 1915, carbon black, a dry soot from the incomplete combustion of natural gas, began its spectacular career as a means for the reinforcement of tire treads against abrasive wear. Since 1920 much research has been undertaken and published (5) upon the effect of many reinforcing agents upon the stress-strain properties of vulcanized rubber. These substances are of especial interest to the engineer, because pure gum vulcanized rubber is highly extensible and its deformation under load is great. On the other hand, compositions which contain certain dry powders in some volume, show stress-strain curves which have a small angle with the axis of stress. Thus vulcanized rubber compounds may have a low or high modulus or any desired intermediate value.

ADHESION OF RUBBER TO METAL

So far as the engineering uses of rubber are concerned, one other discovery is significant. Rubber has been attached to

metal for many years. Yet up to about fifteen years ago no reliable method of obtaining high values of adhesion between soft vulcanized rubber and metal had been found. There were, to be sure, several schemes in common use. The most usual one, if steel were the metal, consisted of cleaning it, of copper or brass-plating it, laying against the brass a thin sheet of a composition which would vulcanize as hard rubber or ebonite, and building against that the soft rubber desired. Then the whole construction was vulcanized together. The weakness in this system was that hard rubber required, and still does, a long period for vulcanization. It was, therefore, practically impossible to obtain these uniform soft-rubber products attached to a uniform hard rubber. One or the other of these two types of rubber suffered in quality.

In 1923 it was found that certain chemical substances, when mixed with rubber and heated, transformed the rubber hydrocarbon into another hydrocarbon of the same chemical composition, but with a different structure. This changed material is known as a rubber isomer, and it possesses a peculiar property of marked adhesion to clean steel. Since this rubber isomer or "Thermoprene," as it is called, is not vulcanized, it has become possible to attach vulcanized rubber to steel with a high degree of physical adhesion or to vulcanize to it any soft rubber composition that might be desired. However, this method of obtaining adhesion possesses a temperature limit above which the isomer softens. Some of the rubber derivatives seem to show promise of development for their adhesive properties.

The period of rubber history from 1918 to the present time has been one of broadening our knowledge of both the chemistry and physics of vulcanized rubber. A large amount of work has been done in the field of the theories of rubber structure, and there has been much research to discover what rubber vulcanization really is, to find out why finely divided powders work as they do, and to study the effects of chemical substances which act as accelerators of vulcanization and inhibitors of oxidation. So today, the state of our knowledge of rubber is of a high order. A rubber composition or compound is subject to exact definition and is reproducible as to properties, whether the mass be small or large. I use this word large somewhat advisedly, because, so far as I know, a great mass such as a cube of three or more feet has never been vulcanized simply because no use has ever been found for it. However, I believe that if you were to call on the rubber industry for a block of vulcanized rubber of the size mentioned, with dimensions and properties from center to surface within reasonable tolerances, the industry would meet such a specification. The period of trial and error in rubber compounding has passed, and for any given purpose within the limitations of vulcanized rubber as a material, uniform products can be obtained.

LIMITING PHYSICAL PROPERTIES OF RUBBER

The limiting physical properties of rubber are several. Its tensile strength is not high when compared with that of metals, and for individual articles it must be supported either by cotton, as in the case of tires, or by steel, as in the case of the rubber springs now in use on trolley cars. Its extensibility is large, its elasticity is high, it has abrasive resistance superior to any other known substance, and it absorbs water but little. It is, however, affected by oil, hydrocarbon oils particularly, which it absorbs and by which it is swollen and weakened. Its physical properties do not vary greatly at temperatures within ordinary atmospheric limits, but above and below that range, temperature effects are notable (6, 7). No catalog of the properties or limits of serviceability of vulcanized rubber is advisable here.

The present-day knowledge of rubber is sufficiently exact to lead engineers to have confidence in it as a material wherever its peculiar physical properties warrant its use. I suppose it is natural for the engineer to look upon rubber as something complex and outside his territory. Mention has been made of crude rubber, sulphur, organic accelerators, antioxidants, dry powders, and their effects. It would appear that vulcanized rubber is a complicated structure. I have spoken of the large number of different rubber articles, and it is obvious that the number of rubber compounds which it is possible to make is extensive. Let me remind you, however, that the field of engineering alloys also deals with large numbers of mixtures. One reference (8) lists 8206 alloys and gives their compositions and uses. Gillett and Mack (9) discuss the various metallic elements entering into this one group of alloy steels alone, and they show, as you well understand, how the proportions of the several metals vary and how small proportions have pronounced effects upon the properties of the resultant alloy.

Quite a complicated subject is the alloy field, at least from the standpoint of the rubber chemist. So, I can see relatively little difference in complexity between alloy steels and vulcanized rubber compositions, except that organic accelerators in their effect upon vulcanization classify themselves somewhat more simply. To be sure, in the field of rubber we have no phase-rule diagrams or photomicrographs to explain the values of carbon black and other ingredients. Rubber is a colloid, and the utility of the organic substances which we use does not depend upon crystal relationships. The fact that rubber requires heat in order to bring it to the desired physical properties means that from the manufacturing standpoint this material is not very different from metallic alloys with which heat-treatment plays such a marked and essential part.

These arguments are introduced merely to show that if the engineer will take an interest in rubber he will find a subject well worth his while. He can gain a sound and constructive understanding of rubber at least as easily as he can of alloys.

MUCH RESEARCH STILL TO BE DONE

Do not let me lead you to believe that the state of knowledge of vulcanized rubber is such that engineers can find data by the application of which large-scale machine-supporting blocks can be designed in the drafting room. Such clearly is not the case. The advances made during the past twenty years have been largely in the chemistry and physical properties of rubber, but application of the product has been confined to relatively small articles. Much research work needs to be done before engineers will be possessed of sufficient data and knowledge of rubber to permit them to design vibration- and shock-absorbing parts for large machines without test by trial and error. The data that we now have are from tests performed upon small pieces, and there is need for research work to permit a translation of small-piece data to terms of large-scale installations.

Such progress as has been made in mounting automobile motors upon rubber blocks, in using rubber springs for automobiles and trolley cars, and in supporting heavy machinery for vibration absorption is of a character pointing rather to the fertility of this field of investigation than indicating a fully developed science.

The time, however, has come when the engineer should take up the study of vulcanized rubber and upon an engineering scale, for until rubber research is graduated from the stage of small test pieces, no great progress can be made. New testing machines must be designed and built. Rubber compositions of several types need study. It does not follow that one type of rubber and one size which may well support a six-cylinder, low-power motor is the best to support a 500-hp motor in a machine shop. We must know the load-deflection curves for

various sizes when rubber is used as a support under compression, under shear, or under extension. Rubber stress-strain curves show extensions of several hundred per cent, yet in engineering service it is probable that small deflections, probably in the order of not over 25 or 50 per cent will be the limits. Mechanical hysteresis needs careful study both on a small and large scale, and the rate of loading and unloading should be varied over a wide range. All these and other physical properties should be studied on a large scale and the tests performed under a range of temperatures and humidities.

I believe the time has come when regular courses in rubber technology should be given in the engineering schools, to give the engineer up-to-date knowledge of the physics and fundamental chemistry of the vulcanized rubber compound.

The history of alloys, cement, and other structural materials shows that the engineer has always been counted on to carry out large-scale investigations and applications. So in rubber the responsibility is upon him in the laboratories of technical schools or industrial plants, to conduct research and make practical use of vulcanized rubber—a highly valuable engineering material.

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BRITAIN WRESTLES *With* UNEMPLOYMENT

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MANY OF THE most pertinent questions of the present day are concerned with unemployment and unemployment relief. To what extent will the social-security measures now beginning to function solve the problems of relief? What national and state policies should be adopted? Should relief be made the concern of the national, state, or local governments? Are we developing a group of unemployed who prefer to remain on relief? These and many other problems have arisen to plague us, and there is no immediate indication that they will vanish overnight.

Needless to say, other countries have been faced with similar problems and have developed methods for dealing with them. Only the narrowest sort of provincial attitude would suggest that we have nothing to learn from their experience.

Fortunately, two excellent studies of British conditions have recently been published, studies which complement each other admirably. The first of these[1] sketches in broad outline the most important aspects of unemployment policy in Great Britain during the last seven or eight years. The second[2] is the report of an intensive investigation of a representative sample of unemployed individuals in areas which exhibit markedly contrasting characteristics.

Either of these studies would provide ample material for several reviews. In order to present a more rounded view, however, it seems desirable to consider them together. Hence, all that can be attempted here is to indicate their general nature and to mention a few of the findings.

Succinctly, occasionally almost dogmatically, but always with insight, Davison traces the course of British unemployment policy since 1930. Neither economic factors, such as the fiscal difficulties of the depression period, nor political complications, national and local, are ignored. The treatment is primarily descriptive, but critical evaluation of policies is by no means entirely lacking.

During the early years of the period under discussion, Britain adhered to the polite fiction that both insurance (contractual) benefits and assistance (relief) payments were part and parcel of the same scheme. In 1931, eligibility requirements for receipt of contractual benefits were so raised that more than half of the registered unemployed were excluded. For those among the latter group who were really "in the labor market," assistance payments were provided, subject to a means test. That is to say, payments were to be made only to the extent of family needs, as determined by an investigation of the resources of the household. That the separation between the two forms of payment was not logically complete, is suggested by the term applied to the assistance payments—transitional benefits.

In 1934, a more formal separation was instituted. The area covered by insurance, narrowly conceived, was more rigidly defined. Within this area, benefits were increased in amount and in duration. Contributions were, as before, required from employers, employees, and the government in equal amounts. The privilege of borrowing from general funds to meet deficits in the unemployment fund was withdrawn. A nonpolitical committee of an advisory nature was set up to watch over the operations of the scheme. In effect, a genuine attempt was made to set up a self-supporting "first line of defense."

So far, at least, results seem to have been satisfactory. Al-

[1] "British Unemployment Policy Since 1930," by Ronald C. Davison. Longmans, Green and Company, 1938.

[2] "Men Without Work—a Report Made to the Pilgrim Trust," Cambridge University Press, 1938.

One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Opinions expressed are those of the reviewer.

most from the start, thanks to improving business conditions, the fund has shown a surplus. By 1937, this amounted to some £62 million. Contributions have been reduced, benefits for child dependents increased, and the waiting period cut from six to three days. It is likely that some of the surplus will be applied to reducing the debt previously incurred by the fund.

The second line of defense, assistance payments to those who could not meet the eligibility requirements for insurance benefits, was in 1934 entrusted to a new agency, the Unemployment Assistance Board. The functions of the new board include, broadly speaking, the administration of relief payments to all able-bodied, necessitous unemployed. (Poverty due to other causes than unemployment remains the concern of the third line of defense, the local Public Assistance Committees.) Centralization of these functions, formerly left almost entirely to local agencies, marked a substantial departure from traditional methods.

The cost of assistance is borne mainly by the national treasury, with small contributions from local authorities. Payments are made only to the extent of family needs, but certain minor sources of family income are generously, and legally, disregarded. It was hoped that uniform rules could be applied throughout the country, and that the whole question of relief could be removed from the pressure of local political forces.

Events, however, showed that the matter was not quite so simple. The board got away to a bad start. Its initial attempts to establish a uniform scale of allowances were greeted with howls of protest, primarily because many of the new allowances were less than those which the local authorities had been paying. Subsequent events cannot be described in detail here. Suffice it to say that the board and the government were forced to backtrack and to start anew, and that later developments have been in the direction of sacrificing uniformity to a considerable degree, of more flexible adjustments to local standards, and of greater reliance upon local committees.

Some of the other developments in British unemployment policy in the last decade can only be mentioned here. By way of contrast to the methods adopted in the United States, it is interesting to note that work relief has, since the early thirties, been definitely abandoned in Great Britain in favor of cash payments without any work requirement. Such minor exceptions as there are to this general statement are concerned with work which is purely voluntary or with the provision of training facilities. These various forms of training opportunities and the measures applicable to certain special areas, particularly hard hit by unemployment, are discussed in the closing chapters of Davison's book. Such broad questions as the effects of unemployment on individuals, or the relations between wages and benefit payments, are touched upon occasionally and briefly.

For more complete evidence on such questions as these, we may turn to the second study, the report to the Pilgrim Trust. If the chief merit of Davison's book lies in its skilful presentation of national policies dealing with the unemployed as a whole, the excellence of "Men Without Work" rests primarily in the thorough analysis of the impact of unemployment and relief upon the unemployed, their families, and their communities.

For those who tend to shy away from compilations of case histories designed to arouse pity, let it be said immediately that this study is not of that nature. To be sure, illustrative cases are frequently presented, but there is no maudlin sentimentality. The authors do not hesitate to point out the weak as well as the strong points of the unemployed persons, and their presentation has an objectivity that is noteworthy.

The study makes no pretense of covering all the phases of unemployment in Great Britain. Essentially it is limited to those individuals who have been "long unemployed," that is, to those employables who have not had any gainful employment for at least one full year. (It is estimated that in 1936, even after several years of recovery, there were 330,000 individuals in this category.) Such evidence as is presented with respect to other groups is incidental to the main body of the report. In each of six localities—ranging from areas with little unemployment to chronically depressed regions in Durham and South Wales—a sample of the long-unemployed was interviewed. Taken in connection with a survey of the general situation in the area and any special measures which had been developed, these interviews provided an illuminating picture of many of the forces which were at work.

It is impossible in a brief space to do anything more than to suggest the range of topics upon which the investigation throws light. A mere listing of a few of these may be informative: Attitude toward unemployment; the sense of independence and respectability; the problem of wages and relief; particular problems of the older and the younger unemployed, and of unemployment among women; clubs for the unemployed; special plans for subsistence production. As may be inferred from this list, rather more emphasis is placed upon those factors which may be broadly termed psychological and sociological than upon those which are more narrowly economic in nature.

It is equally impossible to summarize the findings of the report in any satisfactory fashion. Too many problems are involved, and none of them is simple. Careful studies of unemployment do not produce sweeping generalizations that lead to easy panaceas. Do individuals prefer to be idle on unemployment assistance rather than to work for wages? That, according to the evidence of this investigation, depends. At one end of the scale, there are those who clearly enjoy getting something for nothing. There are also individuals, particularly some of those with large families, for whom no job can be found which will pay enough to provide subsistence. There are others whose standards of respectability and whose traditions make it very difficult for them to accept an inferior job. Then there are those who, even though they are less well off when working, prefer to work because "your money is your own, and that makes all the difference." Many others fall into none of these simplified classifications.

And so with most of the other important questions that arise in connection with unemployment: It depends. Some individuals welcome opportunities for occupational training, others rebel against them, and still others lack the requisite abilities to profit from them. Some persons under some circumstances associate gladly with their fellow unemployed; others try to conceal from their friends even the fact that they are unemployed. Some succumb easily to a feeling of the inevitability of unemployment; others resist it to an extent that adds to their unhappiness. (Many of the older men studied fell into this category.) Some cannot be induced by any means to leave the region in which they live; others unwisely travel long distances in the vain hope of picking up employment.

In short, this study made under the auspices of the Pilgrim Trust offers added confirmation of the complexity of the problems involved in unemployment. True, the report refers only to Great Britain. There is no reason to believe, however, that if similar careful studies were made in the United States, the results would be different in this respect.

Neither of these two studies will bring comfort to those, of whatever shade of opinion, who have a ready formula at hand for dealing with unemployment relief. Neither of them taken by itself pretends to give a fully rounded picture of the situation. Each is weakest where the other is strongest. Taken together, they point the way to a more intelligent understanding of the factors which any country must take into account if its unemployment-relief policies are to be even moderately successful.

Contributions of METALLURGY *to* ENGINEERING PROGRESS[1]

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(Continued from August issue)

NONFERROUS METALS AND ALLOYS

As I intimated earlier in my address, my own interest for the last 40 years has lain almost exclusively in the field of nonferrous metallurgy. Therefore, I wish to give now a brief review of some of the more important developments in that field in which new or improved materials have been placed at the service of the engineer.

In doing this I am compelled by limitation of time to omit many references which not only you but my colleagues in metallurgy may regard as being important. My apology must again be that I am anxious to give you a general rather than a detailed review of the trend of advance, and some selection involving limitation is inevitable.

I would in the first place refer to the remarkable development of alloys of the nickel-copper type. Nickel has quite an extraordinary influence on copper, even when added in only small percentages. The curves in Fig. 1 furnish one example of this, showing that a 2 per cent nickel addition to copper results in raising its strength at high temperatures, not only appreciably above that of copper itself but also above that of several of the commoner copper alloys which at normal temperatures are definitely harder and stronger.

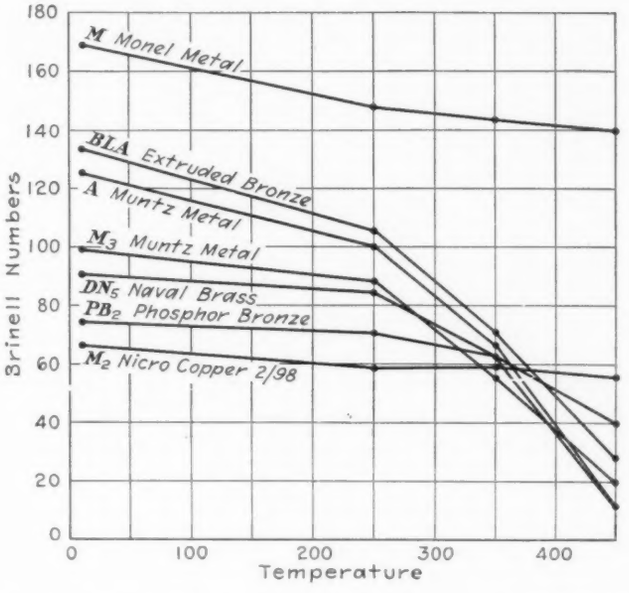


FIG. 1 BRINELL HARDNESS OF VARIOUS NONFERROUS ALLOYS AT HIGH TEMPERATURES

NICKEL-COPPER ALLOYS

As a striking example of a metallurgical contribution to engineering progress in the nickel-copper series of alloys, I select the applications of 70–30 cupronickel to the solution of the condenser-tube-corrosion problem. Before the World War 1914–1918, and indeed during the War, this problem was generally considered one of the most serious with which the marine engineer was faced, and a number of organizations, including the British Institute of Metals, inaugurated researches into the problem, in order to try to discover its causes and cure, particularly with reference to the brass compositions which at that time were invariably used. The alloy 70–30 cupronickel was, of course, known before this time, but the idea of applying it to condenser-tube work was not adopted until it became abundantly evident, as a result of this research work, that brass was inherently inadequate in resistance to corrosion attack. It was soon after the close of the War that one or two English tube manufacturers began experimental work in the production of cupronickel condenser tubes. The first alloy used was the 80–20 composition. It was speedily found that this tube presented considerable advantages over the brass tube. Further experimental work indicated, however, that an increase in the proportion ot nickel resulted in a definite further increase in corrosion resistance. Ultimately, in 1926, the British Admiralty adopted the 70–30 cupronickel condenser tube as standard for all new ships, and this practice has now been followed by practically all other Admiralty departments in the world. This alloy has also been adopted in a large number of the more important new ships in ordinary marine services. It should, however, be pointed out that the investigatory work to which I have previously referred, instituted by the British Institute of Metals and later carried on by the British Non-Ferrous Metals Research Association, ultimately resulted also in considerable improvements in the cheaper brass condenser tube. A copper-zinc alloy with the addition of up to 5 per cent aluminium, known as aluminium brass, has effected a very considerable improvement in this field of corrosion-resistant materials. Although cupronickel still retains its superiority, there are many conditions where corrosion attack is liable to be less severe under which the aluminium-brass tube is giving reasonably satisfactory results.

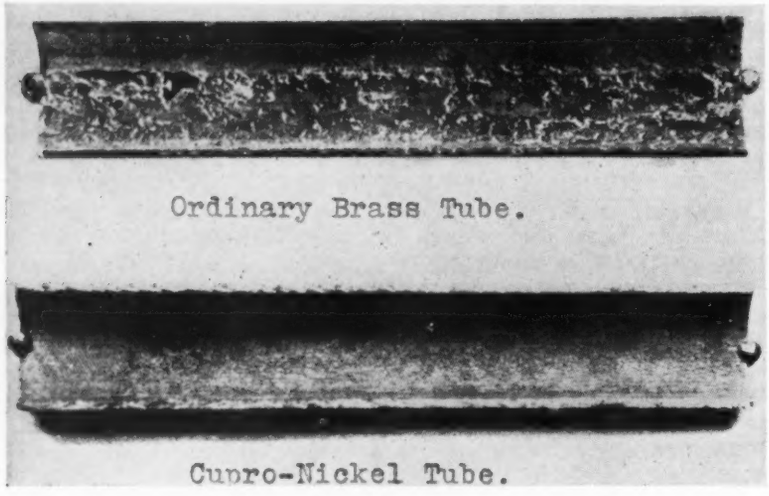
The use of aluminium brasses has been followed by the introduction of aluminium containing cupronickels. One of the resulting alloys, that containing 1.5 per cent aluminium, is worthy of mention as illustrating the striking effects of aluminium on the mechanical properties of such alloys, especially after suitable heat-treatment, as shown in Table 12.

MONEL METAL AND RELATED ALLOYS

Turning now to the nickel-rich end of the nickel-copper series, I am sure that monel metal and its applications are too well known to you to require any lengthy description here. Suf-

[1] The Fourth Calvin W. Rice Memorial Lecture delivered at the Semi-Annual Meeting, St. Louis, Mo., June 20–23, 1938, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. The first part of this lecture was published in the August issue, pages 595 to 600.

[2] Immediate Past-President, Institute of Metals, England.



TUBES AFTER ONE YEAR'S SERVICE ON THE SAME CONDENSER
(Courtesy Allen Everitt & Sons, Ltd.)

fice it to say that within the range of compositions 60–70 nickel we obtain the optimum physical properties of the series, combined not only with a high ductility but exceptionally good corrosion-resisting properties. It is the latter which have proved the greatest single factor in the widespread applications of monel metal in modern engineering, more particularly in recent developments in which its corrosion-resisting properties have been successfully allied with enhanced mechanical strength, a combination of immense value to the engineer, especially in such fields as valve design and construction. I have unfortunately no time to give full details of modern developments in the monel type of alloy, but I may remark that here also the value of aluminium additions has been demonstrated and in K monel, which is an example of an aluminium-containing nickel copper, we have an alloy susceptible to heat-treatment which, when correctly handled, is of front-rank value to the engineer and is proving most successful in giving long life and resistance to corrosion attack under the severest conditions. Particularly have these properties been demonstrated in power and chemical plant and in aeronautical engineering. The physical properties of standard monel metal are compared in Table 13 with the properties of heat-treatable K monel metal.

TABLE 12 EFFECT OF HEAT-TREATMENT ON A NICKEL-COPPER ALLOY CONTAINING 30 PER CENT NICKEL WITH THE ADDITION OF 1.5 PER CENT ALUMINIUM

Treatment	Maximum stress, lb per sq in.	Limit of proportionality, lb per sq in.	Elongation, per cent in 2 in.	Reduction of area, per cent	Brinell hardness number
Water-quenched	60,156	7,168	45	65	90
Water-quenched and reheated	110,312	40,320	32	43	184
Water-quenched, cold drawn 25 per cent reduction in area and reheated	130,144	69,888	16	38	210

TABLE 13 PHYSICAL PROPERTIES OF STANDARD MONEL METAL COMPARED WITH THOSE OF HEAT-TREATABLE K MONEL METAL

Type of monel	Treatment	Maximum stress, lb per sq in.	Limit of proportionality, lb per sq in.	Elongation, per cent in 2 in.	Reduction of area, per cent	Brinell hardness number
Std	Annealed	70,112	26,432	50.0	72	120
Std	Cold drawn, 26% reduction in area	112,448	30,464	19.5	64	200
Std	Cold drawn, 26% reduction in area and strain relief annealed	117,152	69,888	22.0	60	205
K	Water-quenched	78,400	31,360	45.0	65	143
K	Water-quenched and reheated	134,400	78,400	30.0	45	270
K	Water-quenched, cold drawn, 15% reduction in area and reheated	170,240	112,000	20.0	30	310

NICKEL-CHROMIUM ALLOYS

Here again is a series of most valuable engineering alloys which have been almost entirely developed within the present century. The nickel-chromium alloys are not so simple in metallurgical constitution as the nickel-copper alloys, but fortunately the nickel-rich end of the series furnishes a large variety of industrially useful alloys, particularly for electrical-resistance and heat-resisting purposes. The most typical alloy is that containing 80 per cent nickel and 20 per cent chromium, the chief properties of which are given in Table 14 on page 683.

There are, however, a number of other valuable alloys of this type, in which the nickel content varies between 65 and 95 per cent. Of these, an alloy developed by the International Nickel Company under the trade name "Inconel" deserves special mention. It consists of approximately 80 to 82 per cent nickel, 12 to 14 per cent chromium, with iron as the remainder, and possesses extraordinary properties of resistance both as to heat and corrosion. The physical properties of Inconel are given in Table 15.

Appreciable improvements in the heat-resisting properties and "life" of these nickel-chromium alloys have been effected recently by additions of aluminium and/or certain of the rare earth metals, and the service given today by these alloys is greatly in advance of that obtainable even four or five years ago.

TABLE 15 PHYSICAL PROPERTIES OF INCONEL

Type	Tensile strength, lb per sq in.	Yield point, lb per sq in.	Elongation, per cent	Reduction of area, %
Sheet and strip:				
Annealed	78,400– 94,080	29,120–38,080	45–55	...
Rod:				
Annealed	78,400– 94,080	29,120–38,080	45–55	65–75
Cold drawn	98,560–114,240	78,400–94,080	20–30	...
Wire:				
Annealed	78,400– 94,080	29,120–38,080	45–55	...
Spring-tempered	174,720–199,360	.....	...	...

SPECIAL NICKEL-CONTAINING ALLOYS

Many of the modern alloys developed for special engineering requirements are based on the use of nickel, and indeed so striking has been the advance in the use of this element in alloys that it is calculated that there are on the market no fewer than 2300 nickel-containing alloys which have achieved a sufficient standing to bear trade or proprietary marks. One of the most notable series of such alloys is the quaternary nickel-aluminium-cobalt-iron group de-

TABLE 14 THE PROPERTIES OF AN 80 Ni–20 Cr ALLOY

Specific gravity	8.35–8.50
Melting point, C	1400–1420
Specific heat, cgs units	0.106
Coefficient of linear expansion:	
Between 20 and 100 C	0.0000125
Between 20 and 600 C	0.0000150
Mean thermal conductivity at mean temperatures of:	
100 C, cgs units	0.038
220 C, cgs units	0.041
325 C, cgs units	0.045
Electrical resistance, microhms per cc	106–110
Temperature coefficient of electrical resistivity between 20 and 500 C	0.0001
Physical properties of rolled and annealed bar:	
Modulus of elasticity, lb per sq in	31.7×10^{-6}
Proportionality limit, lb per sq in	49,280
Tensile strength, lb per sq in	112,000
Elongation, per cent on $4\sqrt{(\text{area})}$	40
Reduction of area, per cent	55
Brinell hardness number	220–230
Fatigue limit, lb per sq in	±33,600
Physical properties at elevated temperatures and ordinary rate of loading:	
Proportionality limit, lb per sq in., at:	
15 C	49,280
200 C	48,384
400 C	41,664
600 C	27,776
Tensile strength, lb per sq in., at:	
15 C	112,000
200 C	107,968
400 C	107,408
600 C	90,272
800 C	41,216
Elongation, per cent on $4\sqrt{(\text{area})}$, at:	
15 C	40.0
200 C	39.0
400 C	41.0
600 C	23.0
800 C	12.5
Reduction of area, per cent, at:	
15 C	55.0
200 C	54.5
400 C	51.5
600 C	22.0
800 C	14.0
Estimated limiting creep stress, lb per sq in., at:	
500 C	53,760
590 C	35,840
650 C	20,160
700 C	13,440
800 C	4,256

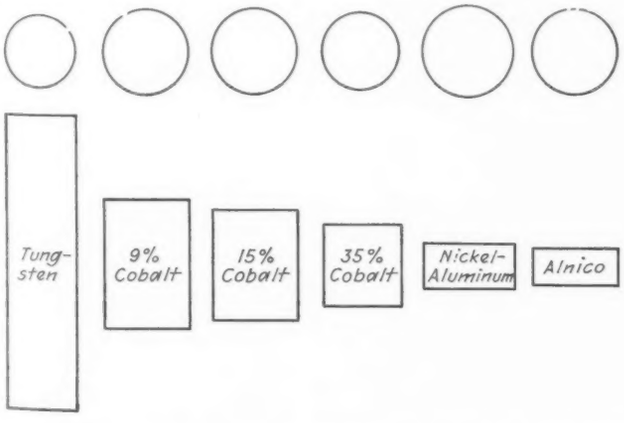
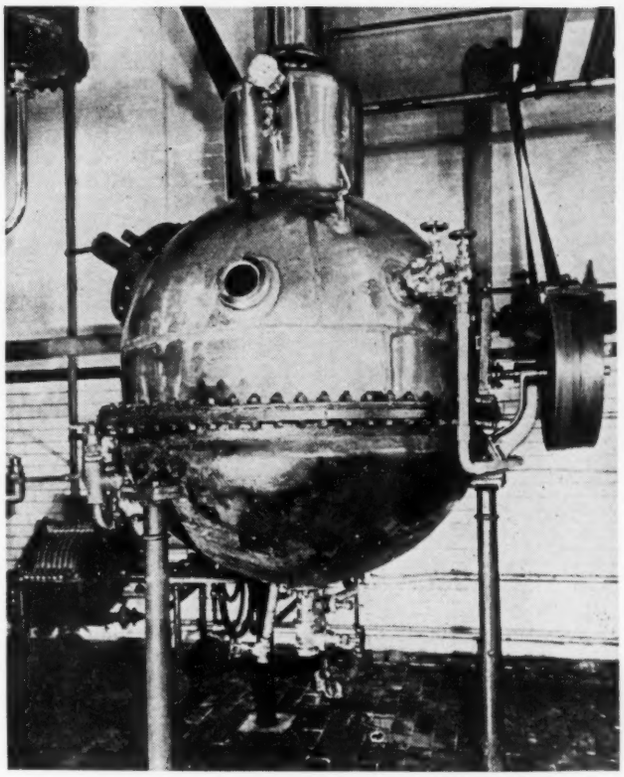


FIG. 2 LENGTHS AND SECTIONS OF MAGNET STEELS FOR THE SAME ENERGY AND PERFORMANCE



INCONEL STEAM-JACKETED VACUUM PAN

veloped during recent years for magnetic uses. At first these alloys were essentially nickel-aluminium steels containing approximately 25 per cent nickel with 13 per cent aluminium, but more recent research work (16)[3] has shown that appreciable advantages are conferred by the addition of cobalt, the approximate composition being 20 per cent nickel, 10 per cent aluminium and 10 per cent cobalt. Fig. 2 illustrates in diagrammatic form the striking advance in magnetic materials thus achieved. The diagram shows the relative length and cross sections, respectively, for materials of different composition required for the same energy and performance.

While on the subject of magnetic properties of modern metallurgical alloys, I must briefly refer to the revolutionary advances that have been made in telegraphic and telephonic engineering by the introduction of such alloys as Permalloy and Mumetal. We have not the time to discuss these in anything like the detail they deserve, but the result of the adoption of these alloys in long-distance cable telegraphy and telephony has been that the speed of working has been increased some six to ten times, and at the same time, by a modification of these high speeds, separate messages are being simultaneously transmitted over the same line. Both sea and land communications have shared in this advance (16).

ALUMINIUM AND LIGHT ALLOYS

The development of alloys of aluminium have been mainly inspired by the demand of the engineer. Pure aluminium, while possessing many valuable engineering properties, is too weak and soft for a number of engineering purposes for which otherwise it is naturally suitable. Throughout the present century, therefore, metallurgists in many countries have been systematically seeking to improve the properties of aluminium

[3] Numbers in parentheses refer to the Bibliography at the end of lecture.

TABLE 16 CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF ALUMINIUM AND ALUMINIUM ALLOYS

Chemical Composition	Elements, per cent									
	Cu	Ni	Si	Mn	Mg	Fe	Ti	Ce	Cr	Al
Aluminium	...	....	....	...	.....	...	.....	....	....	99.5
Duralumin B	3.5–4.5	....	....	0.4–0.7	0.40–0.70	...	.....	....	....	A
Duralumin T	1.5–3.0	0.5–2.00	0.3–1.50	...	0.50–1.25	0.5–1.5	.....	0.05–0.3[a]	0.05–0.3[a]	A
Duralumin E	3.0–4.5	....	1.00[b]	1.2[b]	1.00[b]	1.0[b]	.....	....	....	A
Y alloy	3.5–4.5	1.8–2.30	....	...	1.20–1.70	...	.....	....	....	A
RR 56 alloy	1.5–3.0	0.5–1.50	1.00[b]	...	0.40–1.00	0.8–1.4	0.02–0.12	....	....	A
RR 59 alloy	1.5–2.5	0.5–1.50	1.25[b]	...	1.40–1.80	1.2–1.5	0.02–0.12	....	....	A
RR 50 alloy	0.8–2.0	0.8–1.75	1.5–2.80	...	0.05–0.30	0.8–1.4	0.05–0.25	....	....	A
RR 53 alloy	1.5–2.5	0.5–2.00	2.00[b]	...	1.40–1.80	1.2–1.5	0.02–0.12	....	....	A
RR 53 C alloy	0.8–2.0	0.5–1.50	2.0–3.00	...	0.30–0.80	0.8–1.4	0.30[a,b]	....	....	A

Physical Properties	0.1% proof stress, lb per sq in.	Maximum stress, lb per sq in.	Elongation in 2 in., per cent
Alloy and condition:			
Aluminium, 99.5 per cent:			
Soft sheet	3,360	12,992	40
Half-hard sheet	13,440	17,024	20
Hard sheet	19,040	23,520	10
Duralumin B:			
Heat-treated sheet	35,840	60,480	16
Heat-treated bar	42,560	62,720	16
Heat-treated tube (cold worked)	42,560	60,480	15
Duralumin T:			
Heat-treated bar	51,520	64,960	12
Heat-treated tube	51,520	62,720	12
Duralumin E:			
Heat-treated bar	53,760	69,440	12
Y alloy, completely heat-treated	.....	51,000–60,500	18–24
RR 56 alloy, completely heat-treated	47,050–51,000	60,500–71,700	10–15
RR 59 alloy, completely heat-treated	44,800–49,300	58,250–62,720	10–15
Cast alloys:			
Y alloy, sand-cast, quenched and aged	.....	31,360–35,840	1–3
Y alloy, chill-cast, quenched and aged	.....	40,320–44,800	3–5
RR 50 alloy:			
Sand-cast, precipitation only	20,160–24,650	24,650–29,120	2–4
Die-cast, precipitation only	24,650–29,120	29,120–35,840	4–6
RR 53 alloy:			
Sand-cast, complete	.....	40,320–44,800	0.5–1.0
Die-cast, complete	42,560–49,300	47,050–51,000	0.5–1.5
RR 53C alloy:			
Sand-cast, "solution" only	20,160–22,400	31,360–33,600	2.5–3.0
Sand-cast, complete	40,320–44,800	42,560–49,300	1.0–2.0
Die-cast, "solution" only	22,400–26,880	40,320–44,800	6.0–8.0
Die-cast, complete	42,560–47,050	49,300–53,760	3.0–6.0

A = remainder.
[a] If present.
[b] Less than this amount.

by means of the addition of alloying elements (17). The first and most outstanding achievement in this direction was the production of duralumin in the year 1911, by Wilm.

The production of this material not only marked a distinct advance in the development of aluminium alloys, but also opened up what has now become a very important field, the heat-treatment and precipitation hardening of nonferrous alloys, since the mechanical properties of duralumin are essentially dependent on heat-treatment processes analogous to those used in steel.

Some years after the introduction of duralumin, and as the result of intensive experimental work in the National Physical Laboratory in England, an alloy known as "Y" alloy, possessing somewhat similar properties, was developed, and has reached a position of considerable engineering importance. This Y alloy is valuable in the cast as well as the wrought form, and has the distinctive advantage of possessing good mechanical properties at temperatures higher than normal.

Following the introduction of Y alloy came, in chronological sequence, the development of a group of aluminium alloys resulting from a number of researches carried out in the laboratories of Rolls Royce, Ltd., in England. These alloys, which have become known as the "RR" series, have also achieved considerable industrial importance, and have contributed to the increased efficiency of the internal-combustion engine, particularly for aeronautical requirements. The original RR alloys were developed mainly for foundry purposes and for die castings. They are particularly adaptable for both purposes, but later compositions have been designed for wrought products, and are made available in a large variety of forms such as sheets, tubes, bars, sections, forgings, and drop stampings. One outstanding advantage of the Y and RR type of alloys is their high thermal conductivity as compared with cast iron (the only material formerly available), the aluminium alloys having about three times the thermal conductivity of cast iron. The advantage of this factor is obvious when it is realized that the density of the aluminium alloys is only about one third that of cast iron.

The chemical composition and physical properties of duralumin, Y alloys, and the RR series are shown in Table 16; however, it should be especially noted that the characteristic prop-

TABLE 17 CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF SOME COMMERCIAL MAGNESIUM ALLOYS

Approximate chemical composition, per cent, and condition	0.1% proof stress, lb per sq in.	Maximum stress, lb per sq in.	Elongation, per cent	Area reduction, per cent	Max compression strength, lb per sq in.	Modulus of elasticity, lb per sq in.	Brinell hardness number	Fatigue range, lb per sq in.	Shear stress, lb per sq in.
6.5 Al, 1.5 Zn, 0.5 Mn:									
Annealed sheet	17,920–31,360	40,320–44,800	20–10	23–28	51,520–56,000	6.5×10^6	55–60	±17,920	22,400
Extruded rod	15,680–26,880	40,320–44,800	14–10	20	47,040–51,520	6.0×10^6	55	±15,680	22,400
Forged[a]	20,160–26,880	38,080–44,800	12–10	18–20	53,760–62,720	6.5×10^6	55–60	±17,920	22,400
2.5 Mn (maximum):									
Annealed sheet	13,400–17,920	26,880–33,600	10–7	20	40,320–44,800	6.0×10^6	40	±11,200	17,929
Extruded rod	15,680–20,160	26,880–38,080	10–3	30–25	40,320–49,280	6.0×10^6	40–50	±13,440	17,920
8.5–9.5 Al, 0.2–0.6 Zn, 0.1–0.3 Mn:									
Forged[a]	20,160–31,360	40,320–53,760	15–8	10–15	53,760–62,720	6.5×10^6	65–75	±17,920	22,400
Special specimen[b]	24,640–29,120	40,320–47,040	8–6	...	.....	.....	...	±17,696–19,936	....

[a] Bar 1 in. diameter forged from 2-in. extruded rod.
[b] Specimen cut from a forged airscrew blade.

erties of these materials as used in engineering depend not only on the composition but also on suitable heat-treatment and age hardening.

MAGNESIUM ALLOYS

The development of magnesium alloys during the past ten years has been probably one of the most spectacular in the field of nonferrous metals. In England, for example, ten years ago the total output of magnesium alloys in cast and semimanufactured forms was probably less than 20 tons per annum, whereas today it is of the order of 3000 tons per annum, and is steadily increasing. One of the main reasons for this development is the demand from aeronautical engineers for ultralight materials possessing reasonable strength, and in this connection the advantages of magnesium are obvious, since it has a density of 1.74 as compared with 2.71 the density of aluminium. Research work on magnesium alloys has proceeded very intensively for several years and is still receiving the attention of research metallurgists in every part of the world, especially in Germany.

The limitations of magnesium are fairly well known, particularly its reaction to corrosion by sea water. One direction in which research work has been appreciably successful is in finding addition elements which inhibit this tendency (18). Of the elements available, manganese is probably the most important, and is usually added to magnesium alloys in the proportion of $^1/_2$ to $2^1/_2$ per cent.

Magnesium alloys in the cast form usually contain aluminium and zinc. Table 17 gives a representative series of this class of alloy.

For alloys in the wrought form, i.e., semimanufactured, those containing aluminium without zinc are by far the most important, and in the form of extruded rods, alloys containing from 10 to 12 per cent aluminium have a tensile strength quite comparable to that of the aluminium alloys themselves.

Of developments of still more recent date, mention must be made of the addition of silver and of calcium and cerium. The combination of silver and calcium has considerable value in increasing the resistance of magnesium to oxidation, and the addition of cerium increases strength of the material at high temperatures.

Haughton and Tate, in a paper recently presented to the Institute of Metals (19), referred to an alloy of magnesium containing aluminium and silver, which appears to have appreciable potentialities. Its properties are given in Table 18.

TABLE 18 PHYSICAL PROPERTIES OF A MAGNESIUM ALLOY CONTAINING ALUMINIUM AND SILVER

Chemical composition:	
Magnesium, per cent	92.0
Aluminium, per cent	6.5
Silver, per cent	1.5
Physical properties:	
Ultimate strength, lb per sq in.	61,152.0
Elongation on $4\sqrt{(\text{area})}$, per cent	11.5
0.1 per cent proof stress	21.3
Modulus of elasticity, lb per sq in.	6.5×10^6

As factors in modern engineering progress, few metallurgical contributions during the period I am reviewing have been more outstanding than the light alloys and their applications. The latter have found a place in many spheres of industry, but I am sure that the one that will at once come to your own minds is that of aeronautical engineering. In his Autumn Lecture to the Institute of Metals last year (20), Dr. D. R. Pye, Director of Aeronautical Research to the British Air Ministry, states as an outstanding fact that in six years the maximum power output in air engines, expressed as horsepower per cubic foot of cylinder capacity, has increased by amounts which vary in different designs between 50 and 100 per cent. Dr. Pye goes on to say that in outward appearance the engines separated by this period of six years are very similar, and his reply to the question as to how an output in the latter construction of nearly twice that of the earlier has been achieved is that for the most part this advance has been due to the metallurgist.

DIE-CASTING ALLOYS

I think no survey of modern metallurgical developments of value to the engineer could be allowed to omit the subject of die-casting alloys, to which your own compatriots, the New Jersey Zinc Company, have made so many and valuable contributions.

The production of semimanufactured materials in engineering form by the process of die casting has so many and obvious advantages that I need not occupy your time in detailing them. The requirements of the process are, however, somewhat exacting and it is no small achievement to combine, as has been done, the properties of low melting point and high fluidity with relatively high strength, good machining properties, and quite appreciable resistance to corrosion.

The production of die castings of fine detail, combined with even the thinnest sections, in these days has achieved a very high standard of technique.

Although die-casting alloys now cover a large field, those with a zinc base are still the most outstanding, and I shall content myself here with confining attention to these. As their name implies, they consist usually of zinc to the extent of over 90 per cent, the alloying elements being mainly copper and aluminium, sometimes with small proportions of magnesium and other elements. This class of alloy possesses in the cast condition quite good mechanical properties, including a maxi-

mum strength value up to 50,000 lb per sq in. with Brinell hardness varying from 60 or 65 up to nearly 100. The melting point of zinc die castings is usually of the order of 380 C, a temperature which enables a wide variety of types, shapes, and patterns to be produced without undue wear and tear of dies and tools.

Attention must be directed to the important fact that vital improvements have been made possible in the quality of die-cast products by the use of the appreciably purer raw materials which are now placed at the disposal of manufacturers. The problem of intercrystalline corrosion, which was exceedingly serious in earlier die castings, was shown some time ago to be largely due to the presence of small quantities of impurities, mainly lead, cadmium, and tin, which are of course often found even in the highest qualities of refined zinc.

In recent production of zinc the purity attained is over 99.99 per cent, and this is a vital factor in the modern development and achievement of zinc-base die-casting alloys. This success is a striking example of the services rendered by modern metallurgical research to engineering development. The resulting progress is well illustrated by the fact (21) that in the ten-year period 1926–1936 the consumption of zinc in die-casting alloys in the United States alone increased from 13,500 short tons to 72,000 short tons.

PURE METALS

The reference in the foregoing paragraphs to the vital importance of high standards of purity in the production of the elementary metals in modern alloy production gives me the opportunity of emphasizing the services which have been rendered to both the metallurgical industries directly, and the engineering industries indirectly, by the achievements of metal refiners in producing high-purity metals.

Mention is made under Powder Metallurgy of the production of pure iron. I may also refer to the really astounding achievements of refiners in producing such metals as aluminium, copper, zinc, lead, and cadmium of a standard of 99.99 per cent or over. At first glance this may seem a work of supererogation, or a case of "painting the lily," but modern metallurgical research has shown conclusively that the removal of a few hundredths per cent of impurities from the metals to which I have referred may appreciably affect the engineering and industrial properties of these materials in their elementary state. You will, I am sure, recall one of your earliest laboratory experiments in which it was shown that, while ordinary commercial zinc was attacked most freely by sulphuric acid, the very pure material was extremely resistant, although the percentage difference in composition might be very small.

POWDER METALLURGY

This development is of both actual and potential importance to engineers, and although only in its initial stages, must receive at least brief mention in such a survey as I have undertaken today. It has really brought into existence an entirely new technique in the production of metals and alloys in forms suitable for the engineer (22), and has enabled the metallurgist to manufacture metallic products which hitherto have not been producible. An outstanding example of this new technique is that of ductile metallic tungsten. As you are aware, this element does not melt until a temperature of over 3000 C has been reached; therefore, it is outside our ordinary methods of melting and casting practice. By pressing tungsten powder at a high temperature, however, it is possible to produce a perfectly sound ingot which can subsequently be forged or swaged and drawn or rolled into wire or strip. This technique has been recently applied not only to tungsten itself but to alloys containing it, some of which I think are well worthy of specific notice. I refer to the alloys of tungsten and nickel and copper (23) developed in the Research Laboratories of the General Electric Company of England. Such alloys have a very high density, of the order 17.0, as compared with 11.37 for lead, and possess a correspondingly high absorption coefficient for hard gamma rays, thus rendering them particularly useful and efficient in the care and application of radium. The physical properties of a 4 Cu 6 Ni 90 W alloy are given in Table 19.

TABLE 19 PHYSICAL PROPERTIES A OF 4 Cu 6 Ni 90 W ALLOY

Tensile strength, lb per sq in.	89,600
Yield point, lb per sq in.	82,860
Elongation, per cent in 1 in.	4
Modulus of elasticity, lb per sq in.	32×10^6
Brinell hardness number	290
Density, g per cc	17.1
Coefficient of expansion	5.6×10^{-6}
Thermal conductivity, cgs units	0.25
Specific resistance, ohm per cm	1.16×10^{-5}
Electrical conductivity, $ohm^{-1}\ cm^{-1}$	0.86×10^5

A further and more recent application of these alloys is for balancing crankshafts for internal-combustion engines used in racing cars, and indeed for a whole variety of engineering purposes. In addition to the properties peculiar to themselves, these alloys possess extraordinary resistance to sea water and other analogous corrosion agents.

Some few years ago the I. G. Farbenindustrie of Germany began to produce pure finely divided iron powder by the carbonyl process and the availability of this product has stimulated a considerable amount of research into its possible use. Compressed or sintered carbonyl iron powder furnishes an iron of exceptional purity and hence, ductility, and it is claimed to be more resistant to corrosion than pure iron prepared by melting. Table 20 gives a summary of its properties.

TABLE 20 PHYSICAL PROPERTIES OF IRON POWDER PRODUCED BY THE CARBONYL PROCESS

Yield point, lb per sq in.	15,680–24,192
Maximum stress, lb per sq in.	28,448–39,872
Elongation, per cent	30–40
Reduction of area, per cent	70–80
Brinell hardness	56–80

Such a product has appreciable potentialities where a material of high magnetic permeability is required, and by sintering in an atmosphere of hydrogen it is possible to reduce both carbon and oxygen to a very low limit, so yielding a value of initial permeability of about 2000.[5]

In this field, of course, the nickel-iron alloys are of supreme importance, and since nickel also is produced in powder by the carbonyl method, a valuable series of magnetic alloys is being developed in the range of 40 to 78 per cent nickel, with the remainder iron.

In the purely nonferrous field of powder metallurgy, one of the most important industrial developments up to the present is the production of bronze bearings from nickel, copper, and tin powders. These bearings are porous and may therefore be impregnated with oil to the extent of 25 to 40 per cent by volume. They are already finding some engineering applications, notably in the automobile field. Table 21 gives a summary of tests with such bearings.

Powder metallurgy is also opening up an entirely new field, since we can now look forward to producing by this method

[5] It is interesting to note that the Bell Telephone Laboratories have recently succeeded in obtaining, in a single crystal of Permalloy, a maximum permeability value of 1,330,000.

TABLE 21 RESULTS OF TESTS WITH BRONZE BEARINGS MADE FROM POWDERED NICKEL, COPPER, AND TIN

Bearing no.	Period avg temperature rise, C	Wear on spindle, in.	Wear on bush, in.	Oil at start, per cent	Oil at finish, per cent	Oil consumption, per cent
1[a]	21.8	0	0.0002	29.43	26.37	3.06
2[b]	48.9	0.0002	0.0012	35.19	23.80	11.81
3[c]	8.0[d]	0	0.0004	36.9	31.00	5.90

[a] Bushing diameter = 1 in.; bushing bore = 3/4 in.; bushing length = 1 in.; speed = 2000 rpm (approximately 393 fpm); load = 80 lb per sq in. of area; duration of test = 250 hr = 30,000,000 revolutions.
[b] Bushing diameter = 1 5/8 in.; bushing bore = 1 1/4 in.; bushing length = 1 1/2 in.; speed = 1000 rpm (approximately 390 fpm); load = 60 lb per sq in. of area; duration of test = 4410 hr = 264,500,000 revolutions.
[c] Bushing diameter = 11/16 in.; bushing bore = 0.355 in.; bushing length = 0.659 in.; speed = 9500 rpm (approximately 883 fpm); load = vacuum-cleaner service conditions; duration of test = 800 hr = 456,000,000 revolutions.
[d] Approximately.

alloys from metals which are either wholly or at least partially immiscible in the liquid state.

SOME SPECIAL ALLOYS

Under this heading I venture to call your attention to a few examples of the results which were obtained by modern metallurgical research in improving the engineering properties of the commoner metals by relatively small additions of alloying elements.

Creep Properties of Tin. As you are aware, tin is an example of a metal which has practically no value in this respect, the safe stress allowable being only 150 lb per sq in. (24). By the addition of 3.5 per cent silver and 1 per cent cadmium (24), however, an alloy is obtained in which, when cold-worked and self-annealed, creep resistance is increased by over ten times. Other alloying elements, e.g., lead and cadmium, give similar results.

Lead and Its Resistance to Decay. The failure of lead-cable sheathing by cracking, with resultant breakdown of insulation, was for many years one of the mysteries of electric-cable engineering. In 1924 a systematic research into the problem was undertaken at the Research Department, Woolwich, under the British Non-Ferrous Metals Research Association (25), and as a result, a series of binary or ternary alloys containing tin, antimony, or cadmium (26) in relatively small quantities (of the order 0.25 to 1.5) was developed, which has proved an almost complete solution of the problem. More recently the addition of tellurium to lead (27) has been investigated and it has been found that even in such small proportion as 0.05 this element also has a valuable influence in increasing the strength of lead and its resistance to certain types of corrosion and fatigue.

ALLOYS OF COPPER

Equally interesting and potentially valuable is the addition of small quantities of other elements to copper.

I have previously referred to the power of nickel in increasing the strength of copper. Other recent examples of the influence of such small additions which are proving of engineering value are to be found in chromium, cadmium, beryllium, and other elements.

The addition of chromium to copper (28) is interesting as an example of the effect of an element which can be retained in solid solution to so small a degree as hardly to afford the possibility of marked influence in its mechanical strength. Chromium-copper alloys can, however, by heat-treatment be made to develop improved mechanical properties without seriously affecting electrical conductivity. This effect is being found of considerable engineering value when retention of strength at high temperatures is important. For example, castings of chromium copper containing about 0.5–0.6 chromium, precipitation-hardened between 2 and 2 1/2 hours at 500 C, possess a tensile strength of about 45,000 lb per sq in., a Brinell hardness of about 100, and an electrical conductivity as high as 80 per cent that of pure copper itself.

Cadmium has also been of considerable value, in this connection, for combining strength with high electrical conductivity. With the single exception of silver, cadmium has a less depressing effect on the conductivity of copper than any other element entering into solid solution, and since this effect is combined with an enhanced work-hardening effect the cadmium-copper alloys (up to 1 per cent cadmium) are finding increasing applications for electric-transmission lines, particularly trolley wires. The conductivity of a 1 per cent cadmium copper may be as high as 94 per cent that of copper.

Copper-beryllium alloys, first developed in Germany, and more recently and intensively in the United States, also deserve mention.

The usual range of composition of these alloys is 1.4–2.5 per cent beryllium, and by working and subsequent heat-treatment between 250 and 325 C, a tensile strength as high as 200,000 lb per sq in. can be obtained; even in the ductile (annealed) condition the alloys have a maximum stress value of up to 70,000 lb per sq in. In the wrought form, a large proportion of this alloy goes into springs, particularly in the electrical field. The combination of high strength and resistance to fatigue, coupled with considerable resistance to normal corrosive agents, is most valuable, especially as the material is nonmagnetic.

CONCLUSION

I am sure that after reading the foregoing seriously abbreviated and quite inadequate account of metallurgical contributions to engineering progress you will all be aware that I have left unsaid much more than I have said. I am, however, concerned mainly on this occasion to portray the general position and stimulate your imagination.

There is one thought preeminently in my mind which I must especially emphasize. I referred at the beginning of my address to collaboration between the engineer and the metallurgist. This can and should take many forms, but the one of supreme importance I stress now is cooperation in devising the most efficient and economical use of the raw or semimanufactured materials which are the basis of our joint existence. We live today in a period in which we are trying paradoxically to combine high standards of living with superextravagant expenditure in armaments which essentially mean "waste." I most earnestly trust this extravagance will somehow or other be brought to an end, but the desire of mankind for a high and still higher standard of life is instinctive and will not be denied.

In the ultimate this can be attained only by a strict observance of the laws of economics. In the campaign in Germany for self-sufficiency, one of the great slogans is "eliminate waste," and in that country strenuous efforts are being made to effect this by a reduction in the proportion of scrap made in all metallurgical and engineering operations. The Düsseldorf Exhibition last year furnished many evidences of success in this direction. I believe the need for it is almost as great in the relatively more prosperous countries of the United States and Great Britain. There can be no doubt that we have been in the past and still are hopelessly extravagant in our use of raw material. Can we afford to be so much longer? I think not. The availa-

bility of at least some metals is definitely limited in so far as our present knowledge of the earth's resources extends, but even if ample supplies of all metals were known to be available for many centuries to come, that is no justification for waste. Laws of economics are today lightly held, but like other laws, if not obeyed, the penalties for disobedience must sooner or later be paid in full. The metallurgist is giving to the engineer, almost day by day, new or improved materials capable of bearing greater strain, giving longer life, and resisting more and more successfully the ravages of corrosion. This fact in itself opens great possibilities in the future for the economical use of nature's provisions for man.

One of the greatest factors of progress in this direction is the closest possible cooperation between the metallurgist and the engineer.

The discoveries of the metallurgist, whether on the purely scientific side or in the industrial development of new or improved metallic alloys, depend almost entirely on the engineer for their ultimate usefulness in the service of man. In the light of our extended knowledge of equilibrium diagrams and the structure of metals, it is not in these days very difficult to develop such new alloys. The possible combinations and permutations of ternary, quaternary, and other complex systems are almost infinite, but not one of these can be of real use to mankind until it has been made so by the engineer. Therefore, the work of the metallurgist is only one section of the whole. Sometimes indeed the minor one, for success in all construction depends in the ultimate on the placing of the right material in the right place and in the right relationship. This is preeminently the task of the engineer.

One final word: In all fields of human activity, progress depends to a large extent on the dissemination of information. Such societies as the A.S.M.E. find their greatest justification in this fact, and I believe, therefore, that they stand for something of vital importance to civilization. I plead that we should seek by every means in our power to stimulate this dissemination of information, whether it be positive or negative. Let us ventilate what we know and still more what we do not know, but desire to know.

I end on the note with which I began. I trust I have succeeded not only in giving you information but in arousing your interest and stimulating your search for it.

ACKNOWLEDGMENTS

In the preparation of this lecture it will be obvious that I have gleaned in many fields and have quoted freely from the work of friends and colleagues, to whose readiness to assist me I desire to pay a warm tribute. I should also particularly like to acknowledge the assistance of a few personal friends in the later stages of this work when, owing to illness, I was unable to give necessary attention to details, and particularly to the preparation of illustrations and the compilation of references.

APPENDIX[6]

Although the World War in Europe in 1914–1918 brought untold evils in its train, there is no doubt that, like many other world catastrophes, it gave rise to some good and stimulated progress in many directions, not the least of which was in metallurgical research.

Up to the outbreak of war, Great Britain had no real national interest in what may be termed "industrial research." Research was, of course, being carried on both in pure and applied sicence, but without any appreciable coordination, and certainly with practically no national or government support. The World War brought into existence an entirely new attitude to both research and industry. It was realized that to attain success in war, there must be coordination and cooperation as complete as possible, and that this applied no less to research than to industrial production.

In July, 1915, the British government appointed a committee, under the Privy Council, to organize a Department of Scientific and Industrial Research, and the formation of this committee resulted in the establishment of a series of research associations which, in my view, have been absolutely invaluable to British industry.

One of the earliest of the associations thus formed was the British Non-Ferrous Metals Research Association, which, as its name implies, was established to deal with the problems of nonferrous metallurgy, and many contributions to progress have resulted from its activities. The iron and steel industry has also undertaken cooperative research of this kind, supported by the government, although the details of its organization differ somewhat from those of the nonferrous metals industries.

These semipublic organizations of research work in industry have proved as important in the intangible results they have achieved as in their direct contributions to progress. They have created what I may term an "atmosphere" which is mentally stimulating to all technologists connected with the industry, and many instances have come to my personal notice where firms have been encouraged to pursue researches within their own organization, as a result of thoughts and ideas germinated originally by these cooperative organizations.

We have by no means yet realized to the full the effects of these intangible influences which are extending more and more into even the remotest ramifications of our industry. They are like a stone thrown into the middle of a pond where the ripples produced extend to the very limit of the water, even when they can hardly be seen.

If I were asked to express in a few words the principal achievements of these research associations, I should say that they have made scientific thinking and scientific methods almost habitual in daily processes of manufacture.

This movement, as I have said, is only just beginning, and the future will undoubtedly witness many developments.

A point which must not be overlooked in estimating the value of this research-association movement in Great Britain is that it has accustomed industrialists to the idea and principle of contributing a regular sum, even if only small, to systematic scientific investigations, many of which cannot of necessity attain success except over a long period of years. In other words, industry is thinking for the years ahead instead of only for the present or more immediate future. This is in itself a great gain.

IRON AND STEEL INDUSTRIAL RESEARCH COUNCIL

In the iron and steel industry of Great Britain, cooperative research, although organized in a somewhat different form from that adopted in the nonferrous industries, is based on the same principle of joint financial support by the government and industry. The responsible body concerned is the Iron and Steel Industrial Research Council, which was organized some eight years ago by the British Iron and Steel Federation and the Iron and Steel Institute. This council has set up a number of subcommittees dealing with such subjects as blast-furnace and open-hearth practice, alloy-steel research, corrosion research, and heterogeneity of steel ingots; these committees are in turn

[6] As an appendix to the lecture, a brief account is given of the organization of metallurgical research in Great Britain, and the collaboration of the government with industry and research associations.

closely associated with the industry itself. Some idea of the growth of activity of this organization may be obtained from the fact that its income has risen from about £16,000 in 1933 to £40,000 in 1936.

The various reports of the committees, which have appeared chiefly in the *Journal of the Iron and Steel Institute* during recent years, particularly those on the heterogeneity of steel ingots and on corrosion, give a clear indication of the high standard and wide scope of the council's research work. A leading feature of its program is cooperative investigations in connection with organizations such as the National Physical Laboratory and the technical departments of the Universities of Durham, Glasgow, Leeds, Manchester, Sheffield, and Swansea. The present activities of the Research Council cover a wide field and it is impossible here to give more than a brief outline of its program, but particular mention should be made of blast-furnace technology, of which there is no phase which is not now under examination either from a practical or scientific standpoint. In this connection, particular attention is also being paid to fuels and refractories.

In regard to its purely metallurgical researches, a list of investigations at present in hand is of interest as indicating their general scope. These researches include the following alloy systems: Iron-nickel, iron-nickel-chromium, iron-nickel-chromium-carbon, iron-cobalt, iron-cobalt-carbon, titanium-iron, titanium-iron-carbon, also gases in steel and a considerable number of researches on special subjects connected with industrial ferrous metallurgy.

It is worthy of remark that an important feature of the activities of the Iron and Steel Research Council is that it concerns itself not only with the scientific and technical side of the production of steel, but also with the plant and equipment used and the possibilities of improvements therein. A particularly active section has recently been organized to deal with the problem of rolling, and in this connection both the technique of works' practice and design and construction of rolling mills is being subjected to systematic investigation.

TABLE 22 RESEARCHES IN PROGRESS AND COMPLETED BY THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION[a]

Researches completed before December, 1936:[b]

1 The production of sound ingots of 70–30 brass.
2 Copper: The effect of impurities up to 1 per cent on its properties.
3 Brass: Strip ingot casting. The surface and internal soundness of ingots.
4 Jointing of metals: Including soldering, brazing, and welding of nonferrous materials.
5 Atmospheric corrosion and tarnishing of nonferrous metals; tarnishing of highly polished metals and alloys.
6 The effect of lead in brass for hot forging.
7 Oxidation of brass.
8 Nickel silver: Mechanical properties; also, season and fire cracking.
9 Die-casting-alloys research. Brass and bronze alloys.
10 Gases in copper castings.
11 High-temperature properties of certain nonferrous metals and alloys.
12 Copper locomotive firebox stays.
13 Autogenous welding of copper.
14 Special brasses and high-tensile copper alloys, castings, and worked material.
15 Gases in bronze.
16 Electrodeposition of nickel, copper, chromium, etc.
17 Tin-base bearing metals and lubricants.
18 Aluminium brass condenser tubes.

Researches now in progress:[b]

1 The properties of lead and lead alloys, including the corrosion of lead.
2 Aluminium castings.
3 Copper alloys for high-temperature service.
4 Condenser-tube corrosion (Institute of Metals Corrosion Research).
5 Corrosion of copper (water services, for example).
6 Properties of soft solders.
7 The creep of nonferrous metals and alloys.
8 Elastic properties of metals and alloys.
9 Influence of aluminium on the corrosion, oxidation, and scaling of brass.
10 Electrodeposition of metals.
11 Galvanizing.
12 Melting and casting of bronze.
13 Casting of nickel silver.

[a] Only those of direct engineering interest are included.

[b] In general the results of these investigations are confidential to members of the association, but many of them have been published, after suitable lapse of time, in scientific and technical journals or in the form of books or brochures which are available to the public.

BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION

Since the nonferrous industries of Great Britain have no central industrial organization, this Research Association had of necessity to be built up of individual unit firms or groups. It has, however, from its beginning been generously supported by the copper and brass trade associations and by practically all important firms engaged in these sections of metallurgical industry.

Similar support has also been given by a large number of firms engaged in the nickel, aluminium, tin, zinc, and lead industries, with the result that today it may be said that this association has the backing of every section of the nonferrous metal trades, and in addition the sympathy and support of many engineering users. From very modest beginnings, it has grown to be one of the most important of all the British research associations, and has today an income approximating £30,000 per annum. In Table 22 is given selected lists of its researches completed and in progress.

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DYNAMIC RELATIONS *Between* MOVING LOADS *and* STRUCTURES

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SIMPLE relations between the dynamic qualities of moving loads, such as locomotives, railroad cars, or highway vehicles, and of structures, such as railroad or highway bridges, is the subject of this paper.

The introduction of the so-called impact factor in the building code of bridges makes reference to these dynamic relations, but this gives only an approximate solution. Impact may be defined as the factor by which the static loads are multiplied to allow for possible dynamic effects. Similar considerations have led to elaborate studies of dynamic behavior in aircraft. F. W. Caldwell (1)[1] in his paper describes the corresponding phenomena in airplanes.

A comparison chart, shown in Fig. 1, indicates the wide discrepancies which exist among various countries in the values for the impact factor, thus necessitating a more thorough study of vibration problems. Little doubt remains that the dynamic factor depends not only on the length of the span of the structure, as shown in Fig. 1, but also on the masses of the moving load and structure, the propagation speed, and the elasticity of the springs of the moving load.

Pure mathematical solutions of dynamic problems are very complex and not always satisfactory. Field measurements by themselves only result in records, the interpretation of which is no easy matter. Therefore, from the theoretical and practical viewpoints and for simplification, both the moving load and the structure should be examined separately.

The type of dynamic instruments which might be used for such practical investigations will not be discussed in this paper. Instruments used in airplane tests are thoroughly described by Draper, Bentley, and Willis (2).

Any structure elastically supported is able to vibrate. For moving loads and structures, six degrees of freedom are considered, assuming the road or foundation to be rigid. This holds true for all types of structures, including airplanes.

Fig. 2 illustrates these six degrees of freedom in which the vibrating body itself is rigid. Three of the vibrations are linear in movement; two being horizontal movements in the direction of the *X*- and *Z*-axes, and the other a vertical movement in the *Y*-axis. The other three vibrations are torsional in character and have rotational movements around the *Z*-, *Y*-, and *X*-axes. All these vibrations represent fundamental modes. They may occur simultaneously, that is, be superimposed on one another, and they may contain overtones. On moving loads, these six types of vibrations can be easily recorded. However, certain types of these vibrations do not occur in structures because other kinds of oscillations replace them, due to the elastic connections within the framework. Vibrations of single members of moving loads and the longitudinal, transverse, and torsional vibrations of single members of structures e.g., a bridge truss, have been neglected. Fig. 3 represents the six types of fundamental oscillations at a cross section of a truss in mid-span which can be recorded in the field. Three of the six degrees of freedom, shown in Fig. 2, are omitted, i.e., all vibrations in the direction of propagation, one linear (*b*) and two torsional (*d*) and (*e*). However, three other types of linear oscillations, (*b*), (*d*), and (*e*), replace them, as shown in Fig. 3. In these latter cases the two main girders, or the wind stiffeners, do not vibrate in phase, i.e., in the same direction simultaneously. Hence, besides the vertical oscillations, horizontal vibrations also occur.

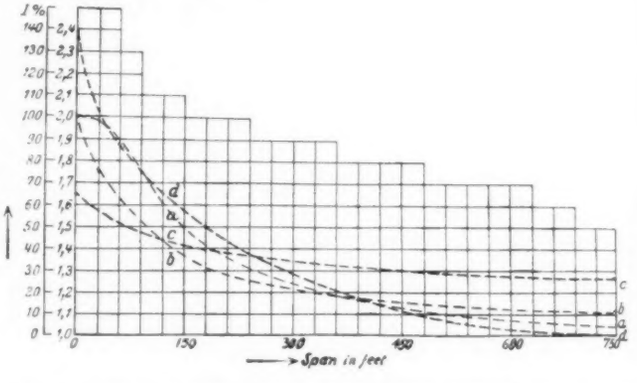

FIG. 1 IMPACT VALUES FOR BRIDGES WITH REFERENCE TO THE SPAN

(*a*, U. S. A.; *b*, Canada; *c*, Germany; and *d*, Spain. *c* indicates values which are too high for longer spans and *d* indicates values too high for shorter spans.)

From the dynamic viewpoint these horizontal or torsional movements indicate the importance of horizontal trusses in structures.

They may be free vibrations, i.e., natural frequencies, or forced vibrations of any frequency. However, even the forced oscillations will adapt themselves in most cases to the previously mentioned fundamental forms. Both types of vibrations, forced as well as free, must be excited by outside forces causing the different types of motions represented in Figs. 2 and 3. These oscillations, periodic or nonperiodic, can be excited by short sharp blows or longer lasting forces of a sine form.

On railroad bridges, these impacts may be caused by flat spots on wheels, tracks in a poor state of maintenance, or unbalanced masses of reciprocating parts of steam locomotives.

The impact generated by the moving load on a bridge, e.g., by flat spots on railroad wheels, might be compared to the so-called "buffeting" phenomenon in airplanes where air, leaving the wing at a high angle of attack, produces a series of severe shocks on the tail. The existence of buffeting and similar phenomena illustrates the need for study of vibration in airplanes, where a large number of elements are found capable of vibrating as units, thus increasing the possibility of coupling

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

Contributed by the Aeronautic Division and presented at the Spring Meeting, Los Angeles, Calif., March 23–25, 1938, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

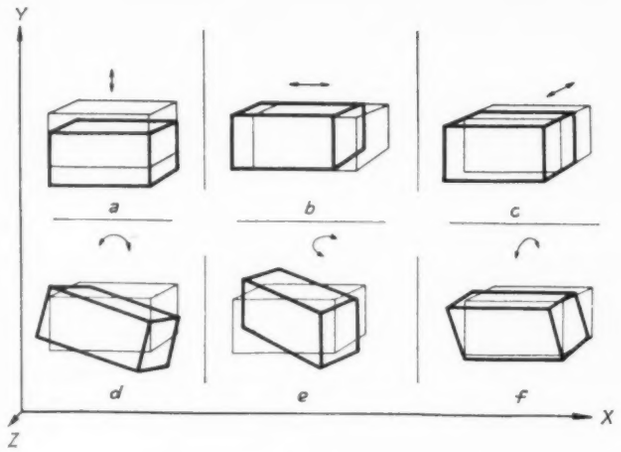

FIG. 2 SIX DEGREES OF FREEDOM OF MOVING LOADS

(*a*, vertical linear movement; *b*, horizontal linear movement in direction of propagation; *c*, horizontal linear movement at right angles to direction of propagation; *d*, torsional movement in plane of sketch; *e* and *f*, torsional movements at right angles to plane of sketch.)

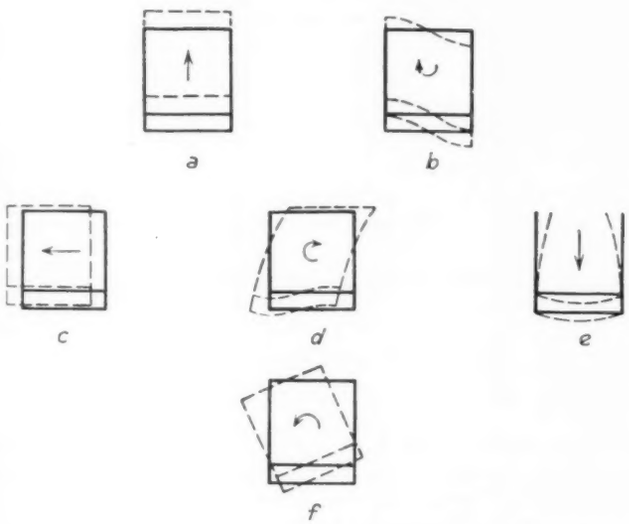

FIG. 3 SIX DEGREES OF FREEDOM OF STRUCTURES AS ILLUSTRATED BY CROSS FRAME IN MIDDLE OF SPAN

(*a*, main trusses vibrate in phase; *b*, main trusses vibrate out of phase; *c*, horizontal trusses vibrate in phase; *d*, horizontal trusses (twisted) vibrate out of phase; *e*, upper chords of main trusses (twisted) vibrate out of phase; and *f*, pure torsional vibration.)

effects resulting in high stresses not easily predictable. Similar phenomena may occur in an airplane while taxiing on the ground or in a seaplane running along on top of the water.

In all dynamic investigations an accurate analysis of the different types of vibrations must be made, especially in the relation of their natural frequencies to other dynamic constants. Minute changes in these dynamic constants, which are easily detected, have led to the discovery of aging effects, and, in certain cases, even to the prediction of actual failures (3). Schlippe (4) describes this more in detail in his paper.

The determination of natural frequencies, both of moving loads and structures, has been carried out with oscillators (5). The apparatus consists of two masses, driven by an electric motor, rotating in opposite directions. By means of these machines, any structure which is capable of oscillating can be excited in any of the required fundamental motions as to amplitude, frequency, and direction, due to the exciting forces or moments.

At the same time, the important dynamic qualities can be calculated by plotting the resonance curves. A resonance curve is obtained by plotting on the horizontal axis the rotational speed of the oscillator, i.e., the frequency of the forced or free vibration of the oscillating system, and on the vertical axis the corresponding power input of the driving motor, i.e., the watts. The damping caused by internal and external friction and the amplifying factor are other important dynamic qualities which can be determined from resonance curves. The amplifying factor represents the increase over the static stresses as a result of dynamic effects and reaches its maximum with the continuous building up of vibrations.

Dynamic investigation by means of oscillators is of importance in airplane design, too. Roché (6) describes an application of this method to airplanes.

CHARACTERISTIC VIBRATIONS OF MOVING LOADS

In this section, only tests on moving loads due to the dynamic relations between moving load and structure will be considered. The dynamic behavior of any moving vehicle is determined by the mass of the body and the arrangement of the springs supporting the body. Oscillations due to elastic deformation within the body are neglected.

In order to obtain the maximum and minimum dynamic values of various types of moving loads, both heavy and light types of locomotives, railroad cars, and automobiles were investigated. Using oscillators to excite the vehicles according to the six degrees of freedom shown in Fig. 2, the heavy vehicles were vibrated with load and the light vehicles without load. Several typical resonance curves are shown in Figs. 4 and 5, representing the results of the tests on the various vehicles.

Resonance curves based on the same principle and similar to those obtained by the author are shown by Theodorsen and Gelalles (7).

The relatively low vertical natural frequencies, below two vibrations per sec, of two locomotives and one railroad passenger car, are interesting. The natural frequencies of the railroad freight cars are relatively higher. This may be due to the fundamental difference in structure. Locomotive and passenger cars have a low substructure which, from the dynamic viewpoint, is independent of the boiler or the body. The substruc-

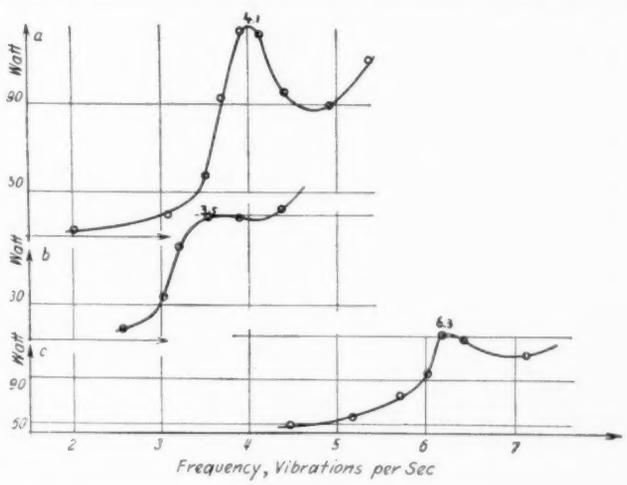

FIG. 4 FREQUENCY–POWER INPUT CURVES OF MOVING LOADS FOR VERTICAL VIBRATIONS

(*a*, 17-ton truck with two axles; *b*, 30-ton truck with three axles; and *c*, 55-ton railroad freight car with four axles.)

ture and body of freight cars give, for certain types, a relatively higher and more rigid unit. The vertical natural frequencies of the motor trucks have a range from three to five vibrations per sec, which coincides with the normal range of vertical natural frequencies of bridges.

The degree of damping of all moving loads, thus far tested, is higher than that for structures. Hence, the corresponding amplifying factor is substantially lower. An obvious explanation for this phenomenon is that the typical system of support of railroad vehicles consists of heavy leaf springs having a high degree of internal damping. Furthermore, the dynamic constants for vertical vibrations, both in the direction of propagation and at 90 degrees to the direction of movement, as well as the torsional oscillations, are almost of the same magnitude. (See Table 1.)

TABLE 1 NATURAL FREQUENCIES, DAMPING COEFFICIENTS, AND AMPLIFYING FACTORS OF RAILWAY AND HIGHWAY MOVING LOADS

	Load		Natural frequency in vibrations per sec				
Type	Description	Condition of loading	Vertical	Horizontal in direction of track	Torsion oblique to track	Damping coefficient	Amplifying factor
Railway Loads							
a Locomotive	Medium-speed engine, on 5 axles	Boiler full, tank empty. Total weight = 62 tons	Under 2.0	6.6	8.7	0.51 0.71 0.90	6.2 4.4 3.5
b Locomotive	High-speed engine, on 6 axles	Full weight = 113.5 tons	Under 2.0	5.4	3.7	0.29 0.77	6.2 3.5
c Passenger coach		Empty	Under 2.0	2.6		0.36	8.7
d Heavy freight car		Loaded with 55 tons of coal	6.3	5.9	5.8	0.37 0.53 0.33	8.5 5.9 9.5
Highway Loads							
e Automobile	30-ton truck with high-pressure tires	Empty	3.5		1.9	1.17 0.79	2.7 4.0
f Automobile	17-ton truck with low-pressure tires	11-ton load	4.13	2.1		0.34 0.50	9.2 6.2

Railroad passenger cars and smaller trucks were not investigated any further because of their relatively light axle pressures. Since structural improvements or better riding conditions of the moving loads are outside the scope of this paper, no conclusions regarding these are made.

CHARACTERISTIC VIBRATIONS OF STRUCTURES

In this part, the study was restricted to simple beams on two supports, i.e., statical determinate structures.

Any such type bridge is usually supported by one fixed and three movable bearings. Each single cross frame may be considered as a three-dimensional body supported by four elastic members. Therefore a structure of this type is able to vibrate as shown in Fig. 3. From the dynamic viewpoint the four trusses, i.e., the two main vertical girders and the two horizontal wind trusses (open bridges have only one horizontal truss), can be replaced by four springs as in (*c*) of Fig. 6. Each spring

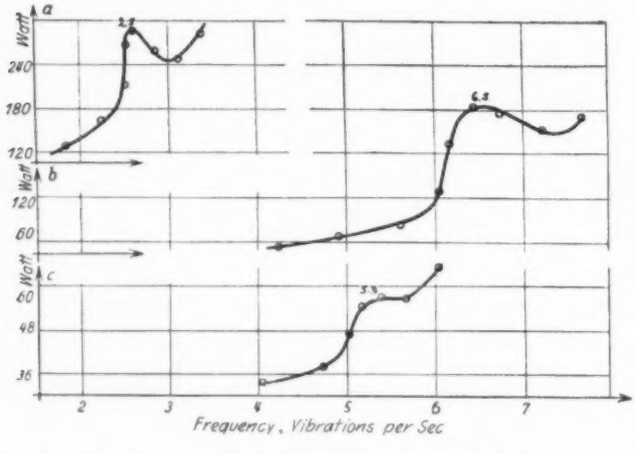

FIG. 5 FREQUENCY–POWER INPUT CURVES OF MOVING LOADS FOR HORIZONTAL VIBRATIONS

(*a*, railroad passenger coach with four axles; *b*, medium-speed locomotive with five axles; and *c*, high-speed locomotive with six axles.)

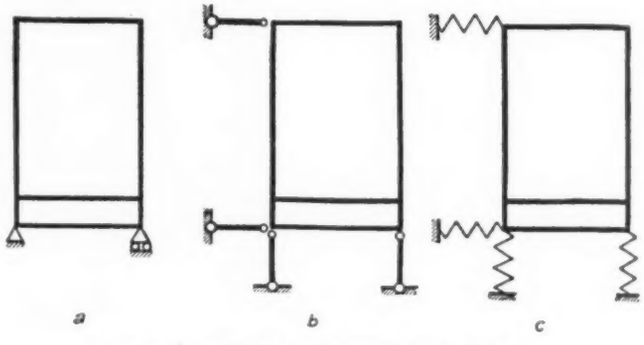

FIG. 6 SUPPORTS OF BRIDGE CROSS FRAME

(*a*, one fixed and one movable support; *b*, four elastic hinged supports—static substitute; and *c*, four springs—dynamic substitute.)

has a characteristic behavior, expressed by what is known as the elastic constant. The elastic constant may be defined as the number of pounds required to deflect the system one inch. It can be determined theoretically by means of the deflection-influence lines (8) of the previously mentioned four trusses or by investigation with an oscillator (5).

In (*a*) and (*b*) of Fig. 3, the main girders are oscillating in a vertical plane, in phase and out of phase, respectively. Exciting forces in (*a*) are vertical impulses and in (*b*) they are couples or moments. Couples can be replaced by eccentric impulses, i.e., impacts caused by one-sided traffic on a two-lane bridge. To simplify the calculation, eccentric forces may be replaced by one couple plus one central load (8). Cases (*c*) to (*e*) are chiefly horizontal oscillations. In (*c*) the two vibrating horizontal trusses are in phase, and in (*d*) out of phase. Exciting forces in (*c*) are horizontal impulses and in (*d*) couples or moments.

A characteristic type of vibration for an open bridge is shown in (*e*) of Fig. 3, where the upper chord members oscillate horizontally and out of phase. However, exciting forces may be both vertical and horizontal impulses. Pure torsional oscillations are shown in (*f*). All four trusses, two main and two horizontal girders, are in phase. Exciting forces may likewise be couples or moments.

The calculation of the natural frequencies of the three main characteristic forms of vibrations, the vertical, horizontal, and

torsional, may be calculated from the following simple formulas.

For vertical vibrations (n in vibrations per sec) corresponding to those in (a) of Fig. 3

$$n = \pi/2 \sqrt{\frac{384}{5}\frac{g}{\delta}} \quad \ldots\ldots[1]$$

where g = force of gravity and δ = vertical deflection of the two main girders due to dead load (9).

For horizontal vibrations, corresponding to (c) of Fig. 3, the vertical deflection δ in formula [1] has to be replaced by the horizontal deflection δ_h. Finally, the torsional vibrations corresponding to (f) of Fig. 3 can be determined by substituting in formula [1] δ for the deflections of the two main girders plus the two horizontal girders, δ_{v+h} due to one-sided loading conditions (8).

The approximate formulas which follow may be used in case the deflections δ, as used in formula [1], are difficult to calculate or to measure. These approximate formulas are based on numerous test results with oscillators.

For vertical vibrations corresponding to (a) of Fig. 3

$$n = \frac{800}{L} \quad \ldots\ldots[2]$$

for horizontal vibrations corresponding to (c) of Fig. 3

$$n = \frac{370}{L} \quad \ldots\ldots[3]$$

and for torsional vibrations corresponding to (f) of Fig. 3

$$n = \frac{935}{L} \quad \ldots\ldots[4]$$

where L = span of bridge in feet. However, calculations to be accurate must be based on the dynamic qualities of both the moving load and the structure.

The natural frequencies of the three main forms of vibrations,

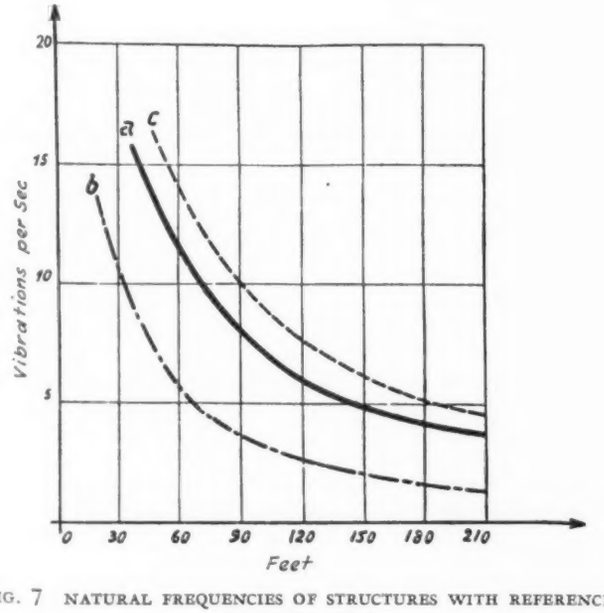

FIG. 7 NATURAL FREQUENCIES OF STRUCTURES WITH REFERENCE TO SPAN LENGTHS

(a, vertical vibrations (n = 800/L vibrations per sec); b, horizontal vibrations (n = 370/L vibrations per sec); and c, torsional vibrations (n = 935/L vibrations per sec) when L = span of bridge in ft and n = natural frequency in vibrations per sec.)

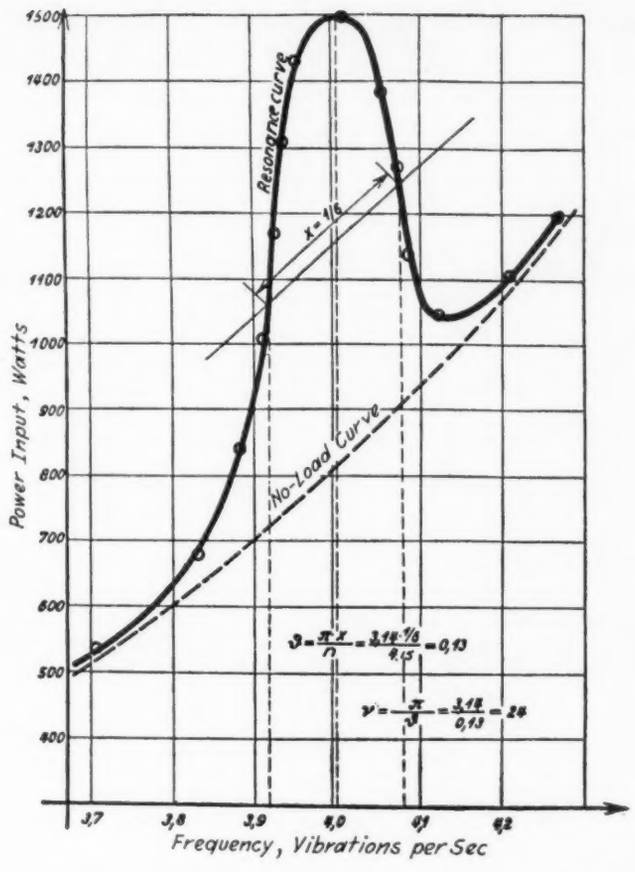

FIG. 8 FREQUENCY–POWER INPUT CURVE (RESONANCE CURVE) FOR VERTICAL VIBRATIONS

$\vartheta = \pi x/n = 3.14.(0.167/4.15) = 0.13$
$\gamma = \pi/\vartheta = 3.14/0.13 = 24$

where x = width of resonance curve in vibrations per sec, measured halfway between maximum watts and no-load curve
ϑ = damping capacity
γ = amplifying factor

resulting from practical tests with oscillators and corresponding to formulas [2], [3], and [4], are shown in Fig. 7. All oscillations of girders out of phase are omitted. Vertical frequencies have a range from 3 to 16 vibrations per sec, horizontal frequencies are somewhat lower, ranging from 2 to 14 vibrations per sec, and torsional frequencies are slightly higher, ranging from 5 to 17 vibrations per sec.

Fig. 8 shows a resonance curve for vertical vibrations plotted from results obtained with an oscillator. The peak of this curve of the natural frequency is 4.15 vibrations per sec. The damping determined from the width of this resonance curve gives an approximate value of 0.13, and an amplifying factor or impact of 24 (5).

A number of tests were made with several structures to determine the three main dynamic qualities, namely, natural frequency, damping, and amplifying factor. Any change of these qualities, particularly due to aging or maintenance, were investigated. Endurance tests on full-size models produced the best results.

No considerable differences between the dynamic qualities of railroad and highway bridges were detected.

DYNAMIC RELATION BETWEEN MOVING LOAD AND STRUCTURE

From a dynamic viewpoint the existing relation between moving load and vehicle is called a "coupling." This coupling

effect is shown in Fig. 9. The supports of the structure may be assumed as rigid. For the elastic structure is substituted the mass m_1, supported by a spring c_1, which connects it with the rigid support. The oscillating moving load may be replaced by a second mass m_2 and connected to m_1 by a second spring c_2.

To simplify the existing conditions between the natural frequencies of vehicle and bridge, only the following limiting cases are considered:

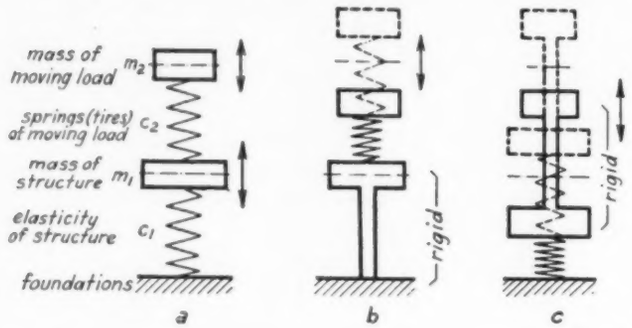

FIG. 9 RELATION BETWEEN MOVING LOAD AND STRUCTURE (DYNAMIC SUBSTITUTE)

(*a*, no movement; *b*, limiting case I, moving load and structure both have different vertical natural frequencies and only vehicle vibrates; and *c*, limiting case II, moving load and structure both have the same vertical natural frequency and therefore both vibrate simultaneously (in phase) and with the same amplitude.)

1 Natural frequencies of vehicle and bridge differ considerably.

(*a*) Only the vehicle is vibrating. The bridge does not oscillate. Springs or tires of highway vehicles vibrate and absorb the movement of the vehicle. See (*b*) of Fig. 9, limiting case 1.

(*b*) Only the bridge is vibrating. The spring-borne part of the vehicle does not oscillate, i.e., boiler of the locomotive or chassis of the automobile remains stationary. In other words the bridge is vibrating under the vehicle. The center of gravity of the moving load does not change its vertical position any substantial amount. See (*b*) of Fig. 10.

2 Natural frequency of vehicle and bridge approximately coincide. Vehicle and bridge vibrate continuously in the same phase (and with amplitudes of the same amount. Springs of the moving load or tires do not vibrate. See (*c*) of Fig. 9, limiting case 2.

In the normal case 2, however, moving load and structure vibrate in such a manner that their maximum amplitudes do not coincide but gradually build up one after the other to form the effect of "beat." This particular case, which might cause a considerable increase in stresses, is discussed later in detail.

It must be kept in mind that the movement of the vehicle causes a change of the vibrating masses and, hence, a change in natural frequency. The spring-borne part, boiler or chassis, may vibrate as shown in (*a*) of Fig. 10, or remain stationary in relation to the absolute space, depending on the absorption of movement by springs or tires as in (*b*) of Fig. 10. Where the vehicle, including spring-borne and nonspring-borne mass, is vibrating as a rigid unit, a considerable change in natural frequency will result because of the movement of the load.

In a one-lane steel bridge with a 90-ft span, the vibrating masses of the structure m_1 are approximately equal to the mass of a heavy locomotive boiler m_2. Therefore, the total vibrating mass is $2m$. When the locomotive is in the middle of the span, as in (*a*) of Fig. 10, the natural frequency will decrease to 0.7 of the natural frequency of the unloaded bridge (9).

To arrive at mathematical solutions of the phenomena, motion formulas for these coupled systems have to be established. The forces of inertia for the mass m_1 of the vibrating structure and for the mass m_2 of the vibrating load, see (*a*) of Fig. 9, are $m_1(d^2x_1/dt^2)$ and $m_2(d^2x_2/dt^2)$ where x_1 and x_2 are the corresponding deflections of m_1 and m_2, respectively. If c_1 and c_2 represent the elastic constants (10) of the two springs, the acting forces of the springs are

$$c_1x_1 \text{ and } c_2x_2$$

No other acting forces are to be considered and the damping forces may be neglected for the present. Then, the motion formula for m_1 becomes

$$m_1x_1 + (c_1 + c_2)\,x_1 - c_2x_2 = 0 \quad \ldots\ldots\ldots\ldots [5]$$

and for m_2 becomes

$$m_2x_2 + c_2x_2 - c_2x_1 = 0 \quad \ldots\ldots\ldots\ldots [6]$$

The further development of these two differential equations, by introducing limiting conditions and some further simplifications are not within the scope of this paper. Theodorsen (11) gives a detailed description of the theory.

As soon as the frequencies of both coupled systems approximately coincide, a considerable exchange of energy between moving load and structure takes place. The amplitudes of the two masses, m_1 and m_2 (see Fig. 9), first increase to a maximum

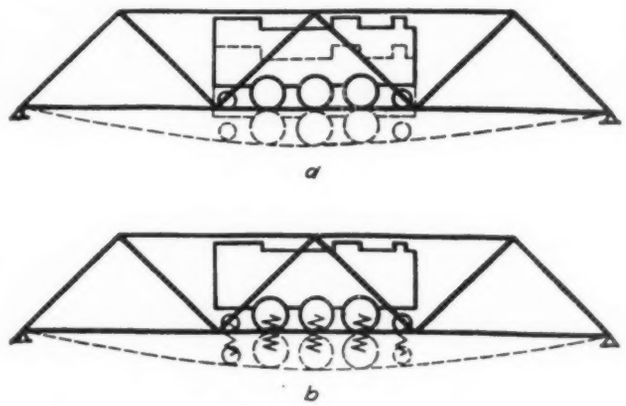

FIG. 10 RELATION BETWEEN LOCOMOTIVE AND BRIDGE DURING PASSAGE OF LOCOMOTIVE

(*a*, spring-borne parts vibrate, hence vibrating masses (both moving load and structure) change; *b*, spring-borne parts do not vibrate and, therefore, vibrating mass (structure) does not change.)

and later decrease to a minimum, but with a pronounced difference in time, i.e., a phase difference. This phenomenon repeats itself continuously. The distance between the two extremes is known as the "time of beat."

The formula for this time of beat (T_s) as well as the following formulas are derived from formulas [5] and [6] (12).

$$T_s = \frac{1}{n_1 - n_2} \quad \ldots\ldots\ldots\ldots [7]$$

where n_1 and n_2 represent the coupling frequencies of the two oscillating systems. These coupling frequencies, i.e., the frequencies of the two vibrating systems in their coupled condition (12), are

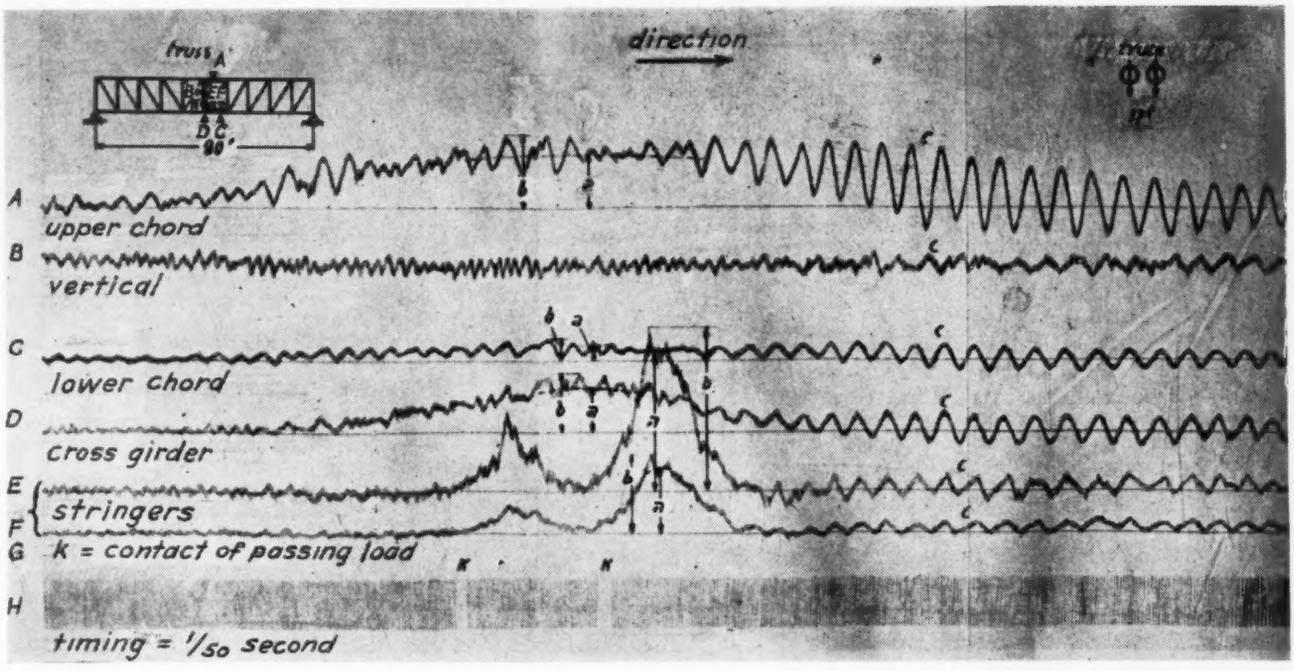

FIG. 11 DYNAMIC STRESS DIAGRAMS OF A STEEL HIGHWAY TRUSS DURING THE PASSAGE OF A 17-TON TRUCK AT A SPEED OF 9.5 MPH (*a*, maximum static stress; *b*, first maximum dynamic stress; and *c*, second maximum dynamic stress.)

$$n = n_0\left(1 \pm \frac{k}{2}\right) \quad \ldots\ldots [8]$$

where n_0 = natural frequency of the uncoupled system and k = coefficient of coupling. Also

$$k = \sqrt{\frac{c_1}{c_1 + c_2}} \quad \ldots\ldots [9]$$

Of special importance is that type of vibration where a complete exchange of energy takes place. At first, one mass starts to vibrate and then stops completely while the other mass oscillates at its maximum amplitude. When the second mass ceases to vibrate, the first mass reaches its maximum amplitude, and so on.

The reason that this theoretical case has been discussed so thoroughly may be explained by means of actual field results. Fig. 11 shows tension and compression diagrams recorded on a highway bridge with a four-lane highway between the lower chord members. Stresses in various members of this truss of a span length of 90 ft were recorded during the passage of a 17-ton truck at a speed of only 9.5 miles per hour. As seen in the diagram *A* at *c*, the structure receives its maximum dynamic stresses shortly before the vehicle leaves the bridge. These dynamic stresses are almost as high as the maximum static stresses which correspond to a static load in the middle of the span. This is clearly observed in the upper chord of the truss *A*. In order to find an explanation for this particular phenomenon, the vertical natural frequencies, both of moving load and structure, had to be determined separately. Oscillator tests revealed a natural frequency for the bridge of 4.15 vibrations per sec (see Fig. 8), and for the truck of 4.13 vibrations per sec (see Table 1*f*). Both frequencies coincide to within $^1/_{50}$ of a vibration per sec.

The other dynamic constants were also determined with oscillators. The elastic constant of the structure was found to be 1,060,000 lb per in. and of the moving load, 17,600 lb per in. Substituting these values in formula [9]

$$k = \sqrt{\frac{17{,}600}{17{,}600 + 1{,}060{,}000}} = 0.128$$

and using formula [8], the coupling frequencies become

$$n_1 = 4.14\left(1 + \frac{0.128}{2}\right) = 4.30$$

$$n_2 = 4.14\left(1 - \frac{0.128}{2}\right) = 3.88$$

Finally, using formula [7] the time of beat is determined

$$T_s = \frac{1}{4.30 - 3.88} = 2.4 \text{ sec}$$

The speed of 9.5 miles per hour for the truck corresponds to 14 ft per sec. Therefore, in 2.4 sec the vehicle moved approximately 33 ft. Since the maximum beat, as shown in Fig. 11, has a distance of 33 ft from the middle of the span, therefore, the point at which the coupling oscillation has been released is indicated. Furthermore, the corresponding cross girder received its maximum stress at this particular instant. On the other hand, the amplitudes of the truck at the same time had decreased to zero.

A second similar maximum, only less pronounced, can be seen in other members of the main girder, *B* and *C*. Oscillations in the cross girders and stringers, *D*, *E*, and *F*, however, revealed mostly natural frequencies which were excited by vibrations of the main girders.

Hence, it is conclusively proved that the dynamic relations between a moving load and a structure is, in certain cases, theoretical and practical as shown in Fig. 9.

Furthermore, this study proved that the oscillations of a structure build up considerably, thereby increasing the impact, and that the span of the structure is, in most cases, only of

secondary influence because of the primary importance of the dynamic relations that exist between moving load and structure.

CONCLUSION

The following conclusions are made if only the vertical oscillations of moving load and structure are considered. As a result of the study on vehicles and bridges, structures have been classified; which classification, in its essentials, agrees with the results given in reports by Hunley, Goodier (13 and 14), and the British Bridge Stress Committee (15).

Railroads

1 In structures with large spans and, therefore, low natural frequencies, a close approximation of the vertical natural frequencies of the moving loads may occur. However, the natural damping, due to the springs of locomotives and heavy freight cars, normally prevents the development of higher impact factors.

2 In structures with medium spans and, therefore, relatively higher natural frequencies, the natural frequency of moving loads need not be considered. On the other hand, it is possible that the unbalanced masses of the reciprocating parts of steam locomotives have the effect of exciting forces. At the higher critical speeds, these exciting forces may coincide with the natural oscillations of the structure and thus lead to considerable vibration with an augmented impact coefficient. However, it must be kept in mind, that any change in frequency of the structure due to the passage of the moving load, tends to prevent the building up of higher amplitudes and, therefore, higher stresses.

3 In structures of short spans and, therefore, a high natural frequency, neither the relatively slow vertical frequencies of the moving load nor the impact due to unbalanced moving parts or flat spots on wheels can cause heavy vibrations because the period of the passage and the influence of the exciting forces are spread over a very short interval of time.

The impulse generated by the moving load on a bridge, e.g., flat spots on railroad wheels, might be compared with the buffeting phenomenon in airplanes where air, leaving the wing at a high angle of attack, causes a series of severe shocks on the tail.

This existence of buffeting and similar phenomena illustrates the necessity for the study of vibration in airplanes, in which are found a large number of elements capable of vibrating as units, thus increasing the possibility of coupling effects resulting in high stresses not easily predictable.

Highways

In highway structures the relations are somewhat different. Exciting forces, caused by unbalanced masses, do not enter into the problem. Shocks due to unevenness in the road surface are almost completely nonperiodic. However, they may lead to considerable vibrations of moving load and structure thereby increasing the impact coefficient. The tires of highway vehicles, with their small damping capacity, make possible a transfer of energy to the bridge and the setting up of the beat phenomenon. The stipulation for a complete transfer of energy envisages the coincidence of both moving load and structure which may result in relatively high impact values and high stresses.

In an airplane similar phenomena may occur while taxiing on the ground or in a seaplane on the water, when hitting the waves.

Highway structures, just as in the case of railroad structures, may be divided into three classes of spans, large, medium, and small.

Acknowledgment is due to the German State Railroads for most of the test data and to H. Sang, J. Lederer, and R. G. Tabor for advice.

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A New Method in Tooling Automatic Screw Machines

(*Continued from page 668*)

bottom in Fig. 5. To produce a fine quality of work, it was necessary to make tapping the final operation. This was a difficult job, owing to the slot and the countersinking operation which was required at both ends. The size of the tap is No. 2-64, and, if the tapping operation were completed prior to the slotting or counterboring, an objectionable burr would be thrown into the thread. The slotting attachment was synchronized to rotate with the work at the same speed, and, in the cutoff position, the auxiliary spindle, which is also synchronized, chucks the work before it is severed from the bar. After the part is cut off, the spindle is partially withdrawn, the counterboring tool moved into place, and the spindle holding the nut moved forward to complete the counterboring operation.

The tap was mounted inside the spindle and was provided with a bent shank, which was mounted on the extreme right end of the mechanism shown in Fig. 2. After the counterboring operation is completed, the spindle is moved in an axial line over the tap, on which a pilot is ground. By this method, tapping is the final operation, which means a clean thread all the way through the nut, and, after running for a considerable length of time, it was found that a class 3 fit could be maintained with little or no difficulty. Secondary operations saved by this method were slotting, counterboring, and tapping, as well as a burring operation on the turned surface after slotting which, of course, saved the customer an equal number of machines and additional operators, as well as considerable floor space.

ENGINEERING'S PART *in the* DEVELOPMENT *of* CIVILIZATION

III—Unfolding of Community Life and Commerce Under the Influence of Engineering

By DUGALD C. JACKSON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN THIS lecture we deal with matters of history instead of the inferences of prehistory—that is, we now will deal with matters of which there is an actual permanent record in the forms of inscriptions and illustrative drawings or descriptive writings. In the earlier centuries of the historical period, the records are not elaborate and often are incomplete. Thus, the earliest record of a ship that has been found (as far as I have chanced to observe) is a simple drawing found in Egypt, and of a wheeled vehicle is a drawing of a chariot also found in Egypt. I should not be surprised personally if the peculiar Chinese wheelbarrow, with its central wheel, which is used for transporting both persons and goods, ultimately would be proved to be among the most ancient of wheeled vehicles.

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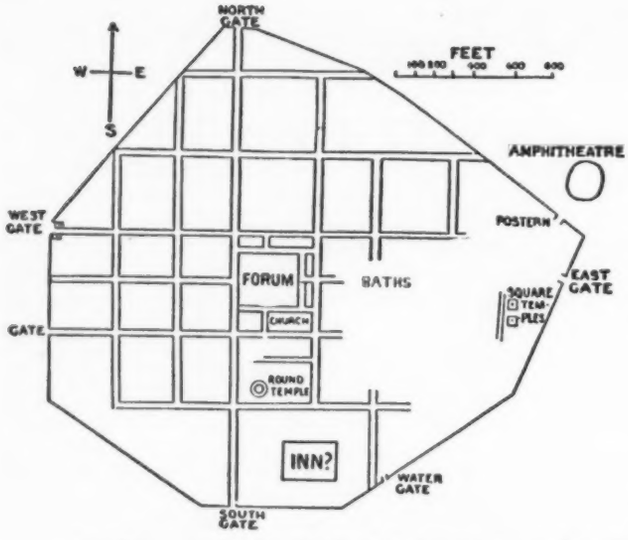
There is considerable probability that further excavations on sites of old-time populations, which now are in progress or may be prosecuted in the future, will uncover fuller and perhaps earlier records of many of man's affairs in the historical age. However, we can accept what we have as authentic as well as interesting and recognize that the antiquity of the given dates within historical time is conservative. For information and facts relating to this early period of history we must rely on the treatises of archaeologists who delve into the disclosures from excavations on old sites of population and who decipher ancient inscribed records which are uncovered.

The Bronze Age of prehistory was still in full influence in most of Europe and Asia, although a little iron had been secured, when the first permanent records were being made in Egypt, Mesopotamia, and elsewhere. Probably much more primitive conditions than those of the Bronze Age existed among a great part of the then population of the earth. For example, the red men of North America still used stone implements when Columbus crossed the Atlantic Ocean. But from such we have no written records. Moreover, the earliest inscribed records apparently were not contemporaneous at the several locations where identified inscriptions have been found. The oldest known permanent inscription dates back about five thousand years. Egypt and Mesopotamia vie with each other for priority, and Crete puts in a persuasive claim. That period therefore sets the date of the dawn of history as we now understand it. Before we again scrutinize conditions influencing the development of civilization let us consider the things that people of fairly early dates in history expressed themselves as wanting—first in rural, and therefore semi-independent, agricultural life; second in a growing community life.

The record of the desires of the rural, seminomadic dwellers is set down by the old Hebrew writers. This record was made some tens of centuries after the earliest historical records but it also was several tens of centuries ago and may serve as an indicator. I will quote from chapter VIII of Deuteronomy (King James Version) regarding the Children of Israel: "For the Lord thy God bringeth thee into a good land, a land of brooks of water, of fountains and depths that spring out of the valleys and hills; a land of wheat, and barley, and vines, and fig trees, and pomegranates; a land of oil olive and honey; a land wherein thou shalt eat bread without scarceness, thou shalt not lack anything in it; a land whose stones are iron, and out of whose hills thou mayest dig brass. When thou hast eaten and art full, then thou shalt bless the Lord thy God for the good land which he hath given thee." Add to that enumeration the flocks and herds that the semipatriarchal people would bring on to the land and you will recognize that all needs for food, clothing, and shelter of a rural people can be fully provided.

In a gathering community, however (which might be exampled by any of various Swiss lake villages of prehistoric time, seacoast villages of early and middle historic times on the eastern shores of the Mediterranean and along the coasts of Italy, prehistoric and early historic riverbank cities of the Nile valley and the area now known as Mesopotamia, as well as others), the desires included access to such a land as that just

Third of a series of six lectures on this subject delivered at the University of North Carolina State College of Agriculture and Engineering, Raleigh, N. C., Jan. 21 to 29, 1938.



. . . . As villages grew into cities their arrangements became more systematic. Plan of early Roman village in England.

(*From Encyclopedia Brittanica, eleventh edition, vol. 4, page 387*)

described, because the inhabitants must from it secure food and material for raiment and shelter, but the desires included also many additional features for the village people. Only the more important of these features will be enumerated here.

Access to the rural country round about was important that food, and raw materials for raiment, implements, and structures, might be brought in. Grains, fruits, olive oil, animals for meat, sun-dried or fire-cured brick and pottery (or clay and sand for making such), stone and metals, wood, all had to be brought in, as well as other articles. A suitable supply of water had to be brought to a place or places available to the users, in contrast to the rural habit of finding the water where it naturally is, in lakes, rivers, brooks, springs, or wells. Measures had to be taken to dispose of wastes of various kinds. Regulations were needed to keep clear passageways conveniently close together through the villages. Some sort of organization was needed to prevent accidental fires from becoming conflagrations, to prevent disorder, to guard against general thievery, and to provide many other features. These are all things that the strictly rural people can get along without, or may find needful only in a moderate way; but they are important to community dwellers even while community life still is crude.

Under the circumstances, land transportation quickly grew up as community dwelling arose. As load carrying was mostly accomplished on the backs of men, asses, or camels, elaborate roads were not imagined, but simple trails became prevalent, similar to coolie paths and the simpler caravan trails still used in primitive areas of Asia and the Pacific Islands. As villages grew into cities, their own arrangements became more systematic. Formal city planning seems to be a rather old profession. It goes back several thousands of years in the East. It has not ceased even to this day to advance in importance in the engineering profession of the West, as city populations have continued to multiply in the world and the development of civilization has proceeded.

As villages grew in population, transportation facilities became of increasing importance, and trails became more organized and definite in character. Road building developed into an engineering art in the neighborhoods of considerable populations; but, for general road building throughout any extensive country, the world found it practicable to wait on the advent of Julius Caesar some 2000 years ago. In the meantime, water transportation took a place of great significance. Sailing and rowing ships are of great antiquity. Archaeological remains indicate that there were ships of some degree of importance on the Tigris and Euphrates Rivers some 6000 years ago.

Shipbuilding, an engineering art, became of importance not only in Mesopotamia but elsewhere in regions of concentrating population. Old Gebal or Byblos near the site of the modern city of Beirut was full of ancient Phoenician shipbuilding and shipping trade. There are even indications that Lebanon timber (from the Phoenician mountains famous for their fir and cedar) was transported from Gebal to the ancient Egyptian city of Memphis, where it was in demand because of the lack of timber in lower Egypt. Selective man does many things which at the first conception and effort take great mental or physical courage, but which, after their demonstration, are taken up by men in general and soon become commonplace. As a Chinese proverb says, "The swallow, though afraid of man, establishes itself among them." It stands to the general welfare of populations to encourage the genius of selective men and to enable them to carry on their work constructively within ethical bounds. Our present national government seems to think it necessary to do things for us instead of encouraging individual self-reliant resourcefulness, and we are suffering unfortunate consequences.

Trade seems to beget trade. That is true today, and records show that it ever has been so. The Phoenicians became great traders by sea and great builders of ships of the kinds which they used. The art of navigation was crude, but observation and experience gave their navigators an engineering sense of the contours and outlines of the sea which served them well. Many enormous oars, as well as sails, were depended upon, and sailing for these Phoenicians was a recourse usually only in a wind from astern. Oarsmen seem to have been an important reliance in warships as late as the battle of Lepanto in 1571; but, for sea-borne commerce, the sailing ship was by then supreme. However, it was as late as the opening of the nineteenth century that Napoleon Bonaparte apparently believed that he could by oars move a troop convoy across the English Channel for a landing attack on England. Shortly thereafter steam power came into use for propelling ships. Engineering has gone for-

. . . . As load carrying was mostly accomplished on the backs of men, asses, or camels, elaborate roads were not imagined, but simple trails became prevalent, similar to coolie paths and the simpler caravan trails still used in primitive areas of Asia . . . .

(*From "The Desert Road to Turkestan," by Owen Lattimore, Little, Brown & Co., Boston, Mass.*)

ward in halting steps, but it has continued to lead civilization forward although its service yet is from time to time abused through evil plans which are originated (usually) by others than engineers.

The Phoenicians were courageous, resourceful inventors and engineers in their field of endeavor, using with fertility the forces of nature as they saw and comprehended them. Their cities prospered, grew more populous, and rules for living, of ethical and legal character, grew up to meet the situation such as have, through history, characterized all such situations of community life.

Other peoples besides the Phoenicians, like the Minoans of the early historic period, also were traders and some became shipbuilders, navigators, and sea traders. This led to piracy, wars, and additional development of rules and legalistic understandings; but rules and understandings which maintain morals only stay in effect where there is constant contact of people within communities, or contact between communities, as in later years when engineering had made constant contact of distant peoples a common matter. The lack of a sense of ethics or any specific morality in the relations between separate cities which is indicated in the works of Homer illustrates the same relationship. These works were composed well after the dawn of history when some sense of ethics was arising among families and among villagers who were in close contact with each other. A general lack of broad interest in ethics and specific morals by the Greeks as late as mid-history may be inferred from the immorality and dishonesty which their writers ascribed to the Olympian gods. Even in these present days we need to confess that we are not yet making the most of our moral possibilities in following our engineering development.

ETHICS AND MORALS

The fact that those rural dwellers in early historical times, who were living close to nature, with few human contacts except in the family, and without resort to the conveniences which might be conferred on them by an acquaintance with engineering of their day, were restrained by neither common honesty nor morals in contacts outside of the family or group of families is illustrated by quotations, to which I venture to call your attention, from the Book of Genesis in the Old Testament. The Hebrew Abram had gone to Egypt with his wife Sarai, who was "a fair woman to look upon," and Abram feared assassination by the Egyptians who might covet possession of his wife. He said to Sarai: "Say, I pray thee, thou art my sister, that it may be well with me for thy sake; and my soul shall live because of thee." This dishonesty is reported by the old Hebrew records to have brought tribulation to the Egyptian House of Pharaoh, but Abram and Sarai apparently received no punishment for the lie. Indeed, Abram later repeated the lie to Abimelech, king of the Philistines. Again, the Hebrew Isaac with his wife Rebekah temporarily dwelt in the Philistine city of Gerar—"And the men of the place asked him of his wife; and he said, She is my sister: for he feared to say, She is my wife; lest, said he, the men of the place should kill me for Rebekah; because she was fair to look upon." Later, he was upbraided for his falsehood by the king in Gerar, but Isaac apparently found no fault with himself.

You will remember the manner in which Jacob swindled his brother Esau and their father Isaac, and other such episodes. Nevertheless, the rules for ethical principles and specific morals among the family and the tribes are set out at length in Deuteronomy; but it is not so for strangers except as they were "within the gates."

Ethics and specific morals became established more broadly than for the family and tribe only after the influence of engineering had enabled people to live in continuous, close community contact; and civilization did not become established while moral relations were a restraining influence only within the family or tribe. Indeed, a true civilization was not needed under such conditions, since in those times competing families or tribes either kept reasonably separate or else, from time to time, fell into combat with the object of swallowing or exterminating one another. An illustration of the tendency to keep reasonably separated may be exhibited by another quotation from the Book of Genesis. When Abram went up out of Egypt with his family, he is said to have been "very rich in cattle, in silver, and in gold." Lot, who went with his family along with Abram, also "had flocks, and herds, and tents," and there was strife between the herdsmen of the two. So Abram said to Lot, "Let there be no strife, I pray thee, between me and thee, and between my herdmen and thy herdmen; for we be brethren." Therefore, they proceeded with their respective caravans in different directions, Abram settling in Canaan and Lot in the Plains of Jordan, where they were far enough separated to obviate conflict between their kindred people; but they had no compunction about strife with the stranger peoples who already occupied the lands upon their arrival.

. . . . cities prospered, grew more populous, and rules for living . . . . grew up to meet the situation . . . . Ruins of Cnossus, ancient capital of Crete.

(*From Baikie's "Sea Kings of Crete," Adam and Charles Black, London, 1920*)

These considerable references to the Old Testament Books of Genesis and Deuteronomy are made as representative of traditions and writings that have come down to us from near mid-history and which are well known to us all. Corresponding references might be made to other sources which also relate to mid-history or earlier. For illustration, the Egyptian records have by now been rather copiously discovered and deciphered. Breasted,* a noted Egyptologist, ascribes to them the distinction of disclosing the earliest development of moral sentiments and conscience.

Breasted also suggests that the Egyptian disclosures are the earliest relating to civilization; in which he may be right, because much of the early record material comes from sites of Egyptian communities, although the moral attitudes appear to be expressed almost exclusively in application to affairs of the family. He comments that the records unmistakably disclose the family as the primary influence in the rise and development

* "The Dawn of Conscience," by J. H. Breasted, Charles Scribner's Sons, New York, N. Y., 1933.

. . . . rapidly rising activity in scientific investigation and improved engineering. We have come to the period of William Gilbert . . . .

(From a painting entitled "Dr. William Gilbert Shewing His Experiments on Electricity to Queen Elizabeth and Her Court" hanging in the board room of the A.I.E.E.)

of moral ideas. Certainly, the people of ancient Memphis possessed no sense of morals toward outlander peoples, and extreme cruelty was a feature of the relations of the religious and monarchical hierarchy toward the ordinary residents of Memphis. But, as Breasted says, "civilization in its broadest aspects is the product of long social evolution."

It was not until the development of engineering arts enabled communities with increasing populations to exist comfortably, that diverse families and tribes were impelled to live in friendly contact with each other, and the universal brotherhood of man became an announced doctrine, which doctrine was enunciated for the West through the life of Christ. Civilization, in the sense of regard for general and mutual welfare, as distinguished from a selfish, cultural coterie, rests on that doctrine; that is, civilization differs from savagery in the contrast of the security, comforts, conveniences, and intellectual amenities of life, but it is not true civilization unless its structure rests on a basic sympathy by all for the individual welfare of all human beings within the circle of contact.

The trail of growing commerce and the growth of cities, encouraged by man's growing command over nature's forces, early skirted the Mediterranean Sea and followed up rivers like the Nile, the Tigris, and the Euphrates. It ultimately crept along the Atlantic Coast of Europe and into the North Sea, along the west coast of Africa, and down the Red Sea and across the Indian Ocean. Then, as the engineering arts became more fully enlarged in the hand of man, Columbus and others discovered and explored the islands and coasts of North and South America and Vasco da Gama rounded the Cape of Good Hope and arrived at India, with corresponding expansion of the opportunities of commerce.

HOW CITIES GREW

We have now reached the sixteenth century of the Christian era in this recital, but let us go back and look at the manner in which cities grew up to take part in these opportunities for commerce.

Tyre, Sidon, Carthage, Venice, Genoa, and other early cities of the Mediterranean Sea grew to their importance almost wholly on account of their water-borne commerce and the skill of their people in engineering works which made possible the use of shipping for commerce and war. Carthage, a city of which there is no physical semblance left, except a few traces for archaeologists to unwind, is reputed to have at one time possessed one million inhabitants, an enormous number for its early day. It was founded by the Phoenicians as a trading center some 2760 years ago on a site already in use over a period of some ten centuries, and was destroyed by the Romans 676 years after its foundation. Other cities which might be enlarged upon were, like Carthage, very active in commerce, but prior to modern times never vied in population with Carthage's reputed number. Venice and Genoa, as well as some others, have held high importance in commercial affairs until this present day, and they are still of influential commercial activity.

Tyre, the best-known city of the Phoenicians, was principally located on an island close to the Syrian coast and it still exists as a small community about fifty miles south of the modern city of Beirut. It was founded in very early history and for centuries existed in great commercial and engineering activity. Although Phoenicia for a good part of its activity was subject to the suzerainty of Egypt, Assyria, Babylonia, or Persia (war and vassalage then being rife in the world), the Phoenicians were a people of great independent activity. They founded Carthage and constructed its harbors. They founded colonies and marine trading points in Italy, in Sicily, on the coasts of Spain, and the west coast of Africa. Perhaps they aided in extending activities of the Bronze Age (the age of bronze tools and weapons which followed the Stone Age) around the Mediterranean Sea, for copper was available in the island of Cyprus and in Spain and tin ore was to be obtained in northwest Spain and the Scilly Islands, in which regions the Phoenicians are supposed to have traded. The bronze used in the Bronze Age contained from a few per cent to ten per cent of tin along with the copper, and most of it must have been an intentionally made alloy.

The Phoenicians also were inventors and manufacturers in addition to being daring navigators and traders. They carried metals to all parts of the Mediterranean area, and to them is ascribed the special dye made from shellfish, called Tyrian purple, which provided the color for imperial-purple garments of old times. It seems to have been as natural to the citizens of Phoenicia, and especially of the city of Tyre, to exhibit engineering courage, initiative, and industry as it is for turpentine to flow through the cells of the yellow-pine trees of our own Carolinas.

The infectious influence of greatness is equally notable in designs of machines and structures as in literature and art; and these Phoenician people carried from port to port, by means of their trading ships, the knowledge of nature and the arts of all the Mediterranean world and its tributary inland territory. From out of this, to a considerable degree, arose the engineering applications which made increased community life practicable at those ports and consequently led to the more general application of ethical principles which underlie civilization. Skepticism often is expressed regarding the greatness of the Phoenicians, but there seems to be no doubt of the unrivaled status which they held in their time as the notably active "middlemen" in trade throughout the Mediterranean Sea and along the Atlantic coast.

Much of the success of old-time engineering was due to strong powers of observation and an instinctive sense of the relative fitness of things; and, possessing these powers, the Phoenicians

not only carried influences from port to port but also brought them back to their own homes. The achievements of these people of mid-history and earlier is impressive, for they stamped their influence over a wide sphere. They were an understanding people and theirs was one of the earliest examples of a wide-flung imagination. The engineering life is guided by the understanding; but, to be fertile and creative, the understanding must be accompanied by an active imagination for its wife. The Phoenicians responded to this touchstone, and their influences contributed notably to the growth of communities and the associated spread of ethical thought. They, indeed, to use a Chinese apothegm, "Plucked a whisker from the beard of fame."

Perhaps we should here consider and dwell upon the word imagination. What is this thing referred to as imagination? As the word is here used, imagination is the power to set up in the mind's eye a picture of one's own experience and one's otherwise secured knowledge of the past and the present, then to picture the future as a stream flowing out from the past through the present, while seeing what progress is desirable and what concrete steps forward, to advance the forefront of progress, may be successfully taken now. Material progress, of the kind from which ethical and moral progress flows, depends on an understanding of nature and cooperation with her, not doggedly and individually like the Chinese farmers, but conjointly and in group cooperation as engineers and traders as was characteristic of these Phoenicians.

SPREADING OF KNOWLEDGE A CATALYST

All through prehistory and the early part of historical time, knowledge was mostly the affair of individuals or communities who had secured it by their own or their ancestors' efforts. This was at the bottom of the extreme slowness of the progress of civilization in the earlier days of history, and the spreading of knowledge through the shipping, colonizing, and commercial activities of the Phoenicians was a catalytic agency in accelerating the progress of civilization. Perhaps other Mediterranean peoples, such as the Minoans of Crete and elsewhere in the Aegean Sea, or the Egyptians, had also a hand in this. There are archaeological remains that indicate a connection between Egypt and the Phoenician city of Byblos as early as some 6000 or 7000 years ago, but that does not give assurance that the Egyptians had entered upon general shipping and trading enterprises. Greek trading during the last half of the pre-Christian period of history also aided in disseminating cosmopolitan thinking to the eastward through a considerable part of western Asia and to the westward as far as Sicily and western Italy. The achievements of those who set up as Mediterranean navigators, and even ventured beyond the environs of that sea, are seen as sparkling jewels of courage, initiative, and invention when we remember that the mariner's compass was not heard of in Europe until the twelfth century of the Christian era or later.

Similar opportunities for mutual dissemination of knowledge seem to have been considerably later in appearance in the northern parts of Europe. When ships did come into use there, the northerners became courageous and active navigators. Apparently no direct trace has been proved for knowledge of shipbuilding traveling from the Mediterranean to the northern waters. Independent shipbuilding in the Mediterranean, in North Europe, in China may be an illustration of the bursting into flower independently in distant localities of an engineering invention. Apparently an irk is felt of like kind (as impressed on unusual individuals) when men experience like pressure of fatiguing duties or are aroused by a like wish to excel, and invention following a type is the result. This comes from the unusual individuals wherever they live. It is clearly shown by the records that the changes of civilization toward a fuller sense of mutuality among all individuals (which, in completeness makes civilization perfect) have chronologically followed the initiative and originality of engineering invention expressed by an alert-minded few who have been dissatisfied with fatiguing duties in their seeking after security for themselves and families. Those inventions thereafter have contributed to the welfare and comfort of all.

On the other hand, we may as well accept the biological tenet that man's habits and therefore his qualities as a social animal are greatly affected by his environment. This tenet applies even more forcibly to mutually encouraging groups than to individuals. Therefore among such groups, habits become traditions and ultimately reach an authority which is almost equal to natural law. Moreover, there seem to have been "Emily Posts" to aid in every stage of man's civilization, who assumed self-appointed powers over the habits of individuals belonging to the community; and this tended to restrain lethargic-minded individuals from expressing themselves with any originality. The lives of most people, being in traditional paths, are conventional. These people prefer to look, listen, and receive, without exerting themselves to see or understand. Material welfare resulting from the state of science and invention is accepted by them in any generation without reflection and as a matter of fatalism. Such lives are seen to have little influence on the unfolding of civilization. Only the minority of lives are those of people whose powers of resourceful logic drive them to examine the condition of themselves and their fellow people. Whenever these few have turned their efforts to the problems of engineering, civilization has felt the influence. Some human beings have always been, as the poet Shelley says, by their intellectual nature,

> "doomed to penury, disease and crime,"

while others

> ". . . . . taste
> The joys which mingled sense and spirit yield."

It seems that man must be polarized so that he tends constantly toward some goal if he is to accomplish important ends.

. . . . the qualities of civilization turned more helpful faces toward the world . . . . St. Peter's, Rome.

(*From Encyclopedia Britannica, eleventh edition, vol. 2, plate III*)

The Phoenicians seem to have possessed an unusual proportion of such men.

The city nations of Egypt, the Aegean area, Mesopotamia and its neighborhood, vied with Phoenicia in many aspects, but apparently lacked the rugged vigor which their love of adventure and competency as engineers brought out in the Phoenicians. Recent excavations in Mesopotamia (and also in Egypt) have brought into evidence unexpectedly early results of that intellectual guiding of diverse artisan elements into serviceable joint embodiments which is the essence of elementary engineering. Some of these explorations have brought to knowledge impressive examples of early engineering which were carefully planned and executed and were in no respect babes of chance. But in many of these locations the benefits of improved engineering knowledge were localized and thus were prevented from advancing civilization in the world. These benefits indeed were notably applied to the service of special groups, such as kings, nobles, and priestly classes who secured luxury, while the major populations of the communities suffered continual hardships and insecurity and were substantially without the benefits of civilization. Perhaps it was the undue elaboration of luxury by the special classes, associated with decay of external and stimulating competition, which was fundamentally the cause of decay in these regional areas of cultures which were great for their times. China also had an early development in shipping and other engineering arts, but we westerners know little of its early details, and therefore possess no adequate picture of its early civilization.

We know that the Egyptians were skilled in the engineering arts of shipbuilding, quarrying, and masonry construction. They successfully moved and put in place large stones for monoliths and masonry under conditions of difficulty, but apparently made use of hordes of men (mostly belonging in the slave category) for their source of power in such movings. Theirs was but a rudimentary or limited concept of civilization. In Mesopotamia there were exhibited the same engineering skills, and in addition there seems to have been considerable construction of water supply and discharge projects for the palaces. The Minoans had certain similar engineering skills. These several examples go back into early history, but their peoples ultimately were swept away and their works went into decay. The influence of Phoenicia (overrun by enemies though it had been from time to time) and the influence of its colonies remained, because the widespread effect on civilization which had been produced by Phoenicia's wide-flung exchange of products and its founding of cities remained.

THE ROMAN EMPIRE

The Grecian city nations and the nucleus of the Roman empire had risen and were continuing to rise when the Egyptian and Mesopotamian powers were decaying. Each of these new candidates for world attention was a marine power. Each was a great designer and constructor of buildings. The Roman Empire spread, exhibited engineering skill by building notable roads, bridges, water-supply structures, sewers, and massive buildings over western Europe, northern Africa, and western Asia, and also ports for Roman shipping. The Romans pushed their relations in all their wide area by the sword.

The rough Dorian invaders who destroyed the Minoan culture and took possession of the Grecian peninsula and neighboring islands, and tribes that followed the Dorians, after some centuries produced numerous seafaring people and by 500 B.C. had become great traders, eastward and westward. They planted thriving colonies along the northern shore of the Mediterranean Sea. In the meantime they had come to a magnificent development in the fields of art, architecture, literature, and philosophic thought which produced a great influence within their orbit, the effect of which remains with us even until today. However, their social organization, which was founded on a slave economy, led to jealousies and frequent devastating wars between the cities of the peninsula, and Greece ultimately became a dependency of Rome, on the fundamentally Etruscan culture of which nation she left an indelible influence.

Ambition is a nervous thing and does not always foresee its ultimate effect. Conquest and wealth apparently were the objectives of Roman ambition; but the Roman occupation wrought out the engineering foundations for great cities in Spain, France, England, and elsewhere. When the wide-flung Roman Empire went into disintegration and gradually withdrew its commanding hold on outlying regions, the released peoples had already learned from the Romans to use the processes of engineering in preserving community life, with its ethical sense of mutual interest. There was a period of hesitation. Then cities utilized the engineering processes received as a legacy from the Romans, and the impress of ethical principles and specific morals became strengthened. In England these things became, over a long period, reflected in the "common law" with its inherent intent of protecting all industrious and honest persons, even those lacking in political influence, which was an improvement over undiluted Roman jurisprudence.

Active intra-European trade grew up through a period of many centuries during the decay and after the fall of the Roman Empire; and the known tenets of engineering, community life, and practical ethics spread jointly over the area. However, little change occurred in engineering knowledge or engineering practice for many hundreds of years, during which period human misery and human betterment stood side by side with little change of their relative influence on the world.

Then came a burst of improved engineering. Shipbuilding flourished; navigation improved. Columbus and many others found their way to America in the closing decade of the fifteenth century and the opening of the sixteenth. Vasco da Gama found his way around the Cape of Good Hope in 1497 and reached India by sea. Magellan circumnavigated the globe in 1519–1522. And all this was followed in the sixteenth century by rapidly rising activity in scientific investigation and improved engineering. We have come to the period of William Gilbert, Francis Bacon, Galileo, Leonardo da Vinci, Michelangelo, Sangallo, Ammanati, Vermuyden, Labelye, Wren, and others of their general gifts—scientists, artists, architects, and engineers. Some individuals were of note in all four categories.

Increased communications and increased commerce between cities and between peoples followed in the wake of this expansion of engineering and a deeper recognition of mutuality of interests among people became impressed by the additional experience arising from the increased contacts. As a consequence, practical ethics and the qualities of civilization turned more helpful faces toward the world, although the world was still full of warfare.

Men already had moved across the threshold of intellectual accomplishments partaking of the character of simple engineering before the historical era with its written records began. The long series of records within the historical era show that intelligence secured a slowly increasing influence on man's affairs as time progressed. The ideals of civilization slowly expanded under this influence, and mankind seems to have moved falteringly (and perhaps unconsciously) toward the goal of finding available for each individual a joy in accomplishment within ethical bounds. The excitement arising from such accomplishments may become ultimately as influential in attracting votaries as the physical excitement heretofore secured from participating in disorder and warfare.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and also published in MECHANICAL ENGINEERING.

Following is a record of the interpretation of this Committee formulated at the meeting of July 1, 1938, which was subsequently approved by the Council.

CASE NO. 863

(Special Ruling)

Inquiry: May grades C and D of the material provided in Par. U-140 be used for seamless vessels at temperatures up to 450 F if designed in accordance with Par. U-20 and be stamped with the code symbol, the working stress to be a maximum of 18,000 lb per sq in. for grade D, the vessels to be used for noncorrosive service?

Reply: It is the opinion of the Committee that this material may be used for the construction of seamless vessels under the conditions set forth in the inquiry.

Revisions and Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the rules and its codes. Any suggestions for revisions or modification that are approved by the Committee will be recommended for addenda, to be included later in the proper place.

The following proposed revision has been approved for publication as proposed addenda to the code. It is published below with the corresponding paragraph number to identify its location in the code, and is submitted for criticism and approval from anyone interested therein. It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets.

Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

Table P-16. Revised to read:

TABLE P-16 MINIMUM SIZE FOR BOILER OUTLETS FOR SAFETY VALVES FROM FIRE-TUBE BOILERS FOR VARIOUS DISCHARGE CAPACITIES

Gage pressure, lb per sq in.	Size of Boiler Outlet for Safety Valve Connections — Nominal pipe size and actual diameters of pipe sizes, in.													Special sizes (use not recommended)	
	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	3 1/2	4	5	6	8	4 1/2	7
	0.622	0.824	1.049	1.380	1.610	2.067	2.469	3.068	3.548	4.026	5.047	6.065	7.981	4.506	7.023
	Lb of steam per outlet per hour														
15	49	74	131	163	245	391	1159	1792	2396	3085	4845	7000	12120	3865	9390
25	66	99	174	218	326	523	1519	2343	3135	4040	6350	9170	15860	5060	12310
50	107	161	284	354	532	851	2395	3700	4950	6370	10020	14470		7985	19390
75	148	223	393	492	738	1181	3257	5030	6730	8670	13620	19670		10840	
100	189	285	503	629	944	1510	4110	6350	8490	10930	17180			13670	
125	230	346	613	767	1149	1836	4955	7650	10240	13180				16520	
150	272	408	723	904	1355	2158	5800	8960	11980	15430				19330	
175	313	470	835	1040	1561	2497	6635	10260	13720	17660					
200	353	533	941	1178	1766	2826	7470	11550	15450	19880					
225	395	593	1052	1315	1972	3154	8320	12870	17200						
250	437	656	1161	1451	2177	3484	9170	14160	18940						
275							10020	15470							
300							10850	16760							
325							11710	18070							
350							12550	19360							

NOTE: The discharge capacities given in the above table may be interpolated to determine the values for intermediate pressures. For outlets above 2 in. nominal pipe size discharge capacity is derived from the following formula:

$$W = \frac{3330\,A}{V}$$

where W = steam per hour, lb, A = area of actual opening, sq in., V = specific volume of steam, cu ft per lb.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Marine Engineering History

A Short History of Marine and Naval Engineering. By Eng. Capt. Edgar C. Smith, O.B.E., R.N., with a foreword by Major P. J. Cowan, M.B.E., University Press, Cambridge, England, 1938. Cloth, 6 × 9½ in., 376 pp., illus., 18s.

PROBABLY no engineer can resist the appeal of a ship. In some measure we all share Dean Kimball's frequently expressed admiration for the high degree of human and engineering skill that goes into the design, construction, and operation of merchant and naval vessels, for, as Captain Smith makes clear, the history of shipping for the last hundred years has become more and more affected by the contribution of engineers. Every ship is a self-contained unit of organized society, as complete and as self-sufficient as the skill of man can make her, and the larger and more modern she is, the more complete, and the more complex, she becomes. Little there is that man has contrived for his safety and comfort on land that does not appear in some form on a ship. And while ashore there is frequently lack of coordination, on a ship each element must be designed with respect to the whole, just as the members of a human body are formed and developed into a brain-controlled structural mechanism.

All this is obvious enough. What is not so obvious to those who have not spent their lives with ships is the long hard road by which marine engineering has developed. The apparent ease with which a *Queen Mary* or a *Normandie* seems to evolve, once the decision is reached to place a new liner into transatlantic service, conceals, except to those responsible for her, the real difficulties to be encountered and the tortuous pathway of success and failure on which experienced designers have seasoned their judgment and improved their techniques. Rumsey, Fitch, Stevens, and Fulton in America, Miller, Symington, and Bell in Scotland, Périer and the Marquis de Jouffroy d'Abbans in France are not removed so many years in time from today, yet when their proposals to apply the steam engine to the propulsion of ships were made, almost simultaneously, few would listen to them, and none could envisage the complete triumph of mechanical propulsion over the sail that man had used for so many centuries. Reading Captain Smith's history serves to emphasize alike the relative youth and the extraordinary triumph of the power-driven ship and to provide a brief and convenient guide to the development of a remarkable achievement.

It is natural that most of the scene of this naval and marine history is laid in England and Scotland, for here by far the greatest number of ships have been built. But it should not be imagined that developments that took place in other countries are neglected. The influence of great engineers and of developments in other branches of engineering, science, and technology on shipbuilding, and the rivalries of marine engineers and shipbuilders themselves are here unfolded, so that the student can acquire a perspective of trends and accomplishments, as well as follow the developments of such important elements as the engine, the boiler, the propulsion mechanism, the auxiliary devices, materials of construction, size, weight, and horsepower, and many other details. Numerous significant tables, illustrations, and quotations add value and charm to the book. Nor are the men who were responsible for design, construction, and operation neglected; a number of excellent biographical sketches fill this need. Credit is also given to the influence of engineering societies, in whose transactions records of developments are to be found. The internal-combustion engine and electric propulsion are properly noted.

One retains certain impressions when the book is laid down. For example, every development is an excursion into regions of technology, uncharted by experience. Today this is no less true; and the history, like a Greek drama, is not finished. It goes on. One learns what trends bear watching. One feels that the future still holds triumphs and disappointments, unexpected turns in the road that will open up new and vaster fields. One sees, also, the collateral growth of science and experiment, and how one reacts on and stimulates the other.

A short history cannot be complete. There are many subjects that Captain Smith was probably sorely tempted to include. Marine architecture is one—for the emphasis of the book is largely on machinery. Hundreds of gadgets of greater or lesser importance to comfort and safety provide opportunity for greatly extending the scope of the work. A humanist might wish more about men, not the great persons named and acknowledged, but the personnel of the merchant marine and navy in general, without whom ships would rust at their piers or founder at sea. The servicing and maintenance of ships, afloat and in dry dock, must have had an interesting and instructive history. So one's mind runs on, as probably Captain Smith's did also. But the very fact that these subjects rise to taunt the reader confirm the opinion that the engineer will find pleasure and profit in reading the book and place it on his shelves as a valuable work of handy reference. And when new developments are announced, he will be able to run back to beginnings and appraise their significance more accurately because of his perspective.—G. A. S.

Matthew Boulton

Matthew Boulton. By H. W. Dickinson. The University Press, Cambridge; The Macmillan Company, New York, 1937. Cloth, 6⅛ × 9½ in., 218 pp., illus., $4.50.

Reviewed by W. L. Batt, Jr.[1]

WHO was Matthew Boulton? Ask that of any educated man today and ten to one he will be unable to answer. And yet Boulton's fame in his own age, a mere hundred and fifty years ago, stretched from the court of St. Petersburg to the shores of our newly founded nation. But the historians and biographers have been so preoccupied with warriors and political figures that early industrialists like Boulton, who exerted as great an influence on men's lives as his contemporary Edmund Burke, have gone unheralded and forgotten. Mr. Dickinson sets out to remedy this lack.

Boulton was born the son of a Birmingham buckle maker in the year 1728. It

[1] Philadelphia, Pa.

gave him much satisfaction in later life that this was the number of cubic inches in a cubic foot. At fourteen he entered his father's business, and when he came of age he took over its active management. Not long afterward he married a local heiress and, after her premature death, married her younger sister. The very fact that he stayed in manufacturing when it was no longer necessary for support shows his love for it. "The affairs of active business were to him as the breath of his nostrils. It was characteristic of him that he always wanted to be in the forefront, a leader of men and a captain of industry."

His first step in this direction was the erection of a manufactory at Soho near Birmingham in a surprisingly modern attempt at mass production. Rather than have a few manual laborers doing piecework under a master, and all distribution being done by a merchant, Boulton conceived the idea of having artisans in several trades working under one management, and then doing his own selling. Thus he could secure both the manufacturer's and the middleman's profits to himself.

Soho Manufactory became a show place for travelers from all over the world. Dr. Johnson visited it; King George III would have done so had it not been for Boulton's illness at the time. These contacts were largely the result of his taking up the manufacture of Sheffield plate, silver plate, and ormolu (a gilded brass and zinc compound), *objets d'art* designed by artists of repute. These he retailed directly through London exhibitions. On one occasion he was "stuck" with two ormolu clocks which would not sell in London, whereupon Boulton presented them to the Empress Catherine of Russia.

At the age of 38, Boulton began exploring the possibilities of the steam engine in supplementing the uncertain water power at Soho. Aided by the advice of his friend Benjamin Franklin, he experimented with the Newcomen or atmospheric engine. It was in this connection that he heard of the young Scotch engineer, James Watt, and the separate condenser which he had invented. Not for six years, however, did the famous partnership begin.

This steam-engine period of Boulton's manufacturing career was the most important as concerns his influence on the economic life of his own and subsequent ages. Watt provided the inventive genius of the combination. Boulton was essentially practical. He was thoroughly familiar with all the problems of manufacturing and marketing of which Watt knew nothing. Most important of all for the success of the invention, Boulton had contacts in all walks of life and was a genius in human relations, whether with a workman in his plant or the Empress of all the Russias.

In touch as he was with the little world of industry, Boulton realized the crying need of mills for steam power. Writing to Watt in 1781, he says: "The people of London, Manchester and Birmingham are *steam mill mad*. I don't mean to hurry you but I think . . . we should determine to take out a patent for certain methods of producing rotative motion from . . . the fire engine." Watt apparently did not want to face the problem. He was satisfied with the income from the numerous engines they had installed in the Cornwall copper mines—all of a reciprocative type. Not so Boulton. He was always in search of new capital for his numerous projects. He finally convinced Watt of the demand for such an application, and the successful rotative steam engine with his newly invented centrifugal governor was the result.

The Boulton and Watt engines were all assembled at the point of installation. This sounds about as sensible to us as Ford workers bringing the parts of a V-8 to our home and assembling them in our garage. But it was the accepted practice of the day. Only with the building of the Soho Foundry in 1795 were modern centralized methods introduced into steam-engine construction. And this innovation was largely the work of the junior partners, young Boulton and young Watt.

But Boulton Senior was not through his work by any means. As early as 1786 he had applied the steam engine to coining. Because of the laxity of the government in providing copper coinage for the growing commerce of the time, as well as the ease in counterfeiting the inaccurate coinage that the Royal Mint did produce, there was a great need for some such innovation. In view of this public necessity, we cannot begrudge Boulton the obvious gain to himself from any copper coinage, since he had huge interests in Cornwall copper and he dominated the steam-engine market. Moreover, he equipped his own Soho Mint to do the manufacturing. Finally at the age of 69, he received a large government commission. Eleven years later, still active in his various projects, Matthew Boulton died, a much loved and respected man.

The duty of a biographer is to give as clear a picture of his subject as possible. To do this he must master his source materials, using enough of them to give a complete picture yet not enough of them to load the reader with an incomprehensible mass of detail. In this Mr. Dickinson has succeeded very well indeed. One might conceivably take exception to his partiality in such passages as this: "Boulton had his faults—who has not?—but we shall be to them a little kind and say nothing of them." Yet this may be forgiven in view of the work he has done here in bringing tardy recognition to this neglected man. Until now we have thought of Boulton, if we ever thought of him at all, as a shadowy figure connected somehow with the great inventor, James Watt. This work of Mr. Dickinson's obliges us to see him for what he was—a founding father of the industrial age in which we live.

Books Received in Library

ADB-RICHTLINIEN FÜR DEN VORRICHTUNGSBAU. III. ERGÄNZUNGSLIEFERUNG. V.D.I. Verlag, Berlin, 1938. Paper, 6 × 12 in., 10 pp., diagrams, 1.10 rm. Part of a series of instruction sheets, supplementing a report of a German committee on apparatus and machine-tool work. These particular sheets have to do with the proper methods of handling chips produced in various metal-cutting processes so as to avoid interference which they might cause.

AIRPLANE DESIGN. By K. D. Wood. Second edition, published by the author at Purdue University, West Lafayette, Ind., 1937; distributed by the Cornell Co-Op Society, Ithaca, N. Y. Paper, 8 × 11 in., mimeographed, illus., diagrams, charts, tables. In this volume, which is intended as a complement to the author's textbook, "Technical Aerodynamics," the design of the airplane is treated in a thoroughly practical way. Airplane layout and stress-analysis calculations are dealt with comprehensively, with particular emphasis on the economics of design. The text is accompanied by a number of appendixes which contain most of the data needed in carrying a design project through the preliminary stages.

AIRPLANE SERVICING MANUAL. By V. W. Pagé. Norman W. Henley Publishing Co., New York, 1938. Leather, 6 × 9 in., 1000 pp., illus., diagrams, charts, tables, $6. This book is intended to be a reference work for those interested in inspecting and repairing airplane structures, as shop and field mechanics and as airport executives. The methods of maintenance and repair, the organization and equipment of shops, the processes and materials are discussed comprehensively and practically in plain language.

AIRPLANE STRUCTURES. Vol. 1. By A. S. Niles and J. S. Newell. Second edition. John Wiley & Sons, New York, 1938. Leather, 6 × 9 in., 451 pp., diagrams, charts, tables, $5. This work aims to provide a well-rounded textbook covering the application of the fundamental principles of structural theory to practical airplane design. The great development of the subject since the first edition appeared, nine years ago has made division into two volumes necessary. Volume one includes the topics covered in the first twelve chapters of the old edition, thoroughly revised and largely rewritten.

AMERICAN YEAR BOOK, edited by W. M. Schuyler and A. B. Hart. Thomas Nelson & Sons, New York, 1938. Cloth, 5 × 8 in., 993 pp., tables, $7.50. This annual presents a survey of events during the year 1937 in 27 major fields of activity. Economics, business, and science are adequately represented, with surveys of the mineral industries, manufactures, transportation, engineering, and construction. Each topic is handled by a competent specialist. The volume is an exceedingly useful work of reference, from which the salient occurrences of the year can be quickly obtained.

ARMY ENGINEERING. By W. A. Mitchell. Fifth edition. Society of American Military Engineers, Washington, D.C., 1938. Leather, 4 × 7 in., 329 pp., illus., diagrams, charts, tables, $3. "Army engineering" designates that portion of military engineering not included in fortification. As a consequence this United States Military Academy textbook covers mapping, roads, railways, bridges, camouflage, explosives, gasoline engines, power plants, chemicals, and river and harbor engineering from the point of view of military operations. There is also brief information on fortification, although there is a separate text on that subject.

ATM (Archiv für technisches Messen). Lieferungen 78, 79, and 80. R. Oldenbourg, Munich and Berlin, 1937–1938. Paper, 9 × 12 in., illus., diagrams, charts, tables, 1.50 rm each. Three numbers of a monthly publication containing articles describing methods and instruments used in various kinds of technical measurements. The articles are classified according to their subject material.

BEIHEFTE ZUM GESUNDHEITS-INGENIEUR, Reihe 1, Heft 37. DAS BRAUNKOHLENBRIKETT IM NEUZEITLICHEN EISERNEN OFEN. By T. Kayser. R. Oldenbourg, Munich and Berlin, 1938. Paper, 9 × 13 in., 13 pp., illus., diagrams, charts, tables, 2 rm. A report of an investigation on the use of lignite briquets in modern iron stoves. The properties of the briquets and the processes of combustion are discussed and followed by a description of the method, operations, results, and value of the tests on various types of stoves.

BRITISH FISHING AND COASTAL CRAFT, Historical Review and Descriptive Catalogue. London, Science Museum. His Majesty's Stationery Office, 1937. Paper, 6 × 10 in., 84 pp., illus., maps, 2s. (Obtainable from British Library of Information, New York, $0.65.) Prepared as a guide to the exhibits in the Science Museum, London, this pamphlet describes the collection of models of vessels and also gives a review of their historical development. Illustrations of the principal types are included.

British Non-Ferrous Metals Research Association Series No. 473. ELASTIC PROPERTIES OF NON-FERROUS METALS AND ALLOYS: COLLECTED DATA, by J. McKeown and E. D. Ward. British Non-Ferrous Metals Research Association, London, 1938. Linen, 10 × 12 in., 35 pp., charts, tables, 6s. The data presented in this report have been selected after a critical survey of a large mass of published information. Copper, nickel, aluminum, magnesium, gold, silver, the platinum-group metals, and their alloys are included. The elastic properties are presented in tables or graphically, with information on the ultimate tensile strength and elongation of the materials in many cases. A list of sources of the data is included.

CHEMISTRY AND TECHNOLOGY OF RUBBER. (American Chemical Society Monograph No. 74.) By C. C. Davis and J. T. Blake. Reinhold Publishing Corporation, New York, 1937. Cloth, 6 × 9 in., 941 pp., illus., diagrams, charts, tables, $15. A symposium on rubber, consisting of 25 chapters by recognized experts on various phases of its chemistry and technology. Among the subjects treated are the chemical and physical properties of crude and finished rubber, vulcanization, accelerators, latex, rubber derivatives and reclaimed rubber, and a chapter indicating the important literature on rubber.

DEUTSCHE KRAFTFAHRTFORSCHUNG, Heft 1, 2, and 3. Heft 1, Luftwiderstand und Kraftfahrzeugen, Versuche am Fahrzeug und Modell, by C. Schmid; 56 pp., 5 rm. Heft 2, Versuche über die Erwärmung der Bereifung von Personenkraftwagen bei hohen Fahrgeschwindigkeiten; by W. Brunner; 24 pp., 2.25 rm. Heft 3, Leistung und Wirtschaftlichkeit gasgetriebener Fahzeugmotoren, by W. Rixmann; 22 pp., 2.10 rm. V.D.I. Verlag, Berlin, 1938. Paper, 8 × 12 in., illus., diagrams, charts, tables. Researches published by the German Automobile Research Commission covering respectively: (1) Tests on vehicles and models for determining the air resistance of automobiles; (2) heating of tires on passenger automobiles at high speeds; (3) the performance and efficiency of automobile engines utilizing gas.

DICTIONNAIRE TECHNIQUE DU CAOUTCHOUC, Allemand, Anglais, Francais, Russe. By L. Akobjanoff. Revue Générale du Caoutchouc, Paris, 1937. Cloth, 5 × 8 in., 173 pp., 45 fr. A small dictionary containing some two thousand words used in the rubber industry. The first section gives the English terms in alphabetic arrangement, with their French, German, and Russian equivalents. Succeeding sections provide alphabetic lists in the latter three languages, with references to the first section.

DIESEL HAND BOOK. By J. Rosbloom. Fifth edition. Diesel Engineering Institute, Jersey City, N. J., 1938. Leather, 5 × 7 in., 720 pp., illus., diagrams, charts, tables, $5. A practical manual for operators. The fundamentals are presented in simple language. Engine details and auxiliaries and their action are described. The principal American types of engines are presented, and practical advice given on operation, adjustment, and maintenance.

DUODECIMAL ARITHMETIC. By G. S. Terry. Longmans, Green & Co., New York and London, 1938. Cloth, 10 × 12 in., 300 pp., charts, tables, $7.50. Twelve as a base for our number system is strongly advocated in this publication. The author demonstrates the advantages of this system as compared with the base often in various mathematical operations from simple multiplication to the manipulation of the higher mathematical functions. Fully worked-out tables of roots, reciprocals, logarithms, and various functions are included, with examples of their application.

EINFÜHRUNG IN DIE TECHNISCHE SCHWINGUNGSLEHRE. Bd. 1, Einfache Schwinger. By K. Klotter. Julius Springer, Berlin, 1938. Cloth and paper, 7 × 10 in., 206 pp., diagrams, charts, tables; cloth, 19.80 rm.; paper, 18 rm. This is the first part of a three-volume introduction to vibration in engineering. In the present work the characteristics of simple oscillating bodies and mechanisms are considered theoretically. An introductory section on the general theory of vibration is followed by a discussion of the kinetics of simple oscillators under varying conditions of free or forced, damped or undamped vibration, including material on starting effects and maintained vibrations.

ELASTICITY STRUCTURE AND STRENGTH, PHILOSOPHY NATURAL VERSUS SOPHISTICAL for Problems of Astronomy and Physics, Promotion of Progress in Engineering and Chemical Mechanics, and Analysis of the Structure of Matter: Electronics and Organic Functions. Part 2. By C. A. P. Turner. Published by the author, Columbus, Ohio, 1938. Paper, manifold copy, 9 × 12 in., 82 pp., charts. Chemical mechanics is conceived as a science through which the physical properties of matter may be determined quantitatively from chemical structure. The postulation of this structure as triunel, consisting of a group of atoms enclosing an atmosphere of pulsation and enclosed by an atmosphere of vibration of a fundamental ether, and of an inherent relation between atomic weights and various chemical, electrical, and mechanical properties, permits the calculations produced.

ELECTRIC WELDING. By M. H. Potter. American Technical Society, Chicago, 1938. Cloth, 6 × 9 in., 77 pp., illus., diagrams, charts, tables, $1.25. A practical book for the inexperienced welder, describing processes and equipment, methods for various metals, shapes and types of work, the weldability of different metals, and certain special jobs. The last chapter covers power-tube rectifiers and their utilization in welding equipment.

ELEMENTS OF PHYSICS. By A. W. Smith. Fourth edition. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 9 in., 790 pp., illus., diagrams, charts, tables, $3.75. A further revision of a standard textbook on physics, covering under the headings: Mechanics, wave motion and sound, heat, magnetism and electricity, electronics, physical and geometrical optics, radiation and atomic structure, the manifold phases of the modern subject. Two new chapters are devoted to nuclear physics and astrophysics.

ELEMENTS OF STEAM AND GAS POWER ENGINEERING. By A. A. Potter and J. P. Calderwood. Fourth edition. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 8 in., 374 pp., illus., diagrams, charts, tables, $2.75. The beginning chapters cover the fundamentals of thermodynamics, fuels, and combustion. Succeeding chapters cover steam-power-plant machinery, auxiliaries and accessories, and internal-combustion engines, fuels, and auxiliaries. The final chapter treats of the application of steam and gas power to locomotives, automobiles, and airplanes. Problems are included.

ELEMENTS OF THERMODYNAMICS. By E. M. Fernald. Second edition. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 9 in., 330 pp., diagrams, charts, tables, $3.50. A textbook presenting the subject with special reference to its applications in engineering. The customary topics of general phases and states, steam cycles, refrigeration cycles, gas mixtures, compressed air, flow phenomena, combustion, and available energy are included. The last chapter, however, represents an endeavor to present the essential structure of thermodynamics from the viewpoint of pure energy relations.

ENGINEERING MATERIALS AND PROCESSES, Metals and Plastics. By W. H. Clapp and D. S. Clark. International Textbook Co., Scranton, Pa., 1938. Leather, 5 × 9 in., 543 pp., illus., diagrams, charts, tables, $4.50. A concise account of the physical properties, metallurgy, and uses of engineering metals and alloys, together with a description of the methods by which these materials are processed. The book also contains a short chapter on plastics and plastic molding.

EVOLUTION OF PHYSICS. By A. Einstein and L. Infeld. Simon & Schuster, New York, 1938. Cloth, 6 × 8 in., 319 pp., illus., diagrams, charts, tables, $2.50. In this eminently readable volume the author of the theory of rela-

tivity and one of his coworkers describe the evolution of ideas in physical science, from the earliest concepts to the theories of relativity and quanta. The book is intended for the layman without any concrete knowledge of physics and mathematics, is clear and straightforward in style and, obviously, authoritative. The general reader will find it an understandable account of modern views.

Great Britain. Department of Scientific and Industrial Research. FUEL RESEARCH, Physical and Chemical Survey of the National Coal Resources No. 43. THE LEICESTERSHIRE AND SOUTH DERBYSHIRE COALFIELD. SOUTH DERBYSHIRE AREA, THE STOCKINGS SEAM. His Majesty's Stationery Office, London, 1938. Paper, 6 × 10 in., 59 pp., illus., tables, 2s. (Obtainable from British Library of Information, New York, $0.65.) Results of a comprehensive and detailed examination, from floor to roof, of eight pillar sections taken from points distributed over the area of the important coal seam in question. The results of the various analyses are given in tabular form with a summary for the whole seam.

Great Britain, Department of Scientific and Industrial Research. WELDING OF STEEL STRUCTURES. London, His Majesty's Stationery Office, 1938. Paper, 6 × 10 in., 326 pp., illus., diagrams, charts, tables. (Obtainable from British Library of Information, 270 Madison Ave., New York, $1.75.) This important document presents a complete account of the work of the Welding Panel of the Steel Structures Research Committee, from its appointment in 1930 to its dismissal in 1937. The purpose was to obtain reliable information as a basis for the design and construction of welded multistory buildings. The subjects investigated included the strength and reliability of welded joints, nondestructive methods of testing welds, and the fatigue resistance of welded joints. Methods, results, and conclusions are reported. A survey of the existing published data, containing bibliographies, is included.

Great Britain. Department of Scientific and Industrial Research. FUEL RESEARCH Technical Paper No. 44. (The) ACTION OF HYDROGEN UPON COAL, Part 3. (The) Development of a Small-Scale Liquid-Phase Continuous Plant, by N. Booth, F. A. Williams, and J. G. King. His Majesty's Stationery Office, London, 1938. Paper, 6 × 10 in., 27 pp., illus., diagrams, charts, tables. (Obtainable from British Library of Information, New York, $0.30.) Continuing a research on the action of hydrogen upon coal, this part describes the layout and development of a small-scale plant for the continuous hydrogenation of coal in the liquid phase. There is also information concerning the influence of coal composition on the process.

Great Britain. Department of Scientific and Industrial Research. INVESTIGATION OF ATMOSPHERIC POLLUTION, Report on Observations in the year ended March 31, 1937. 23rd Report. His Majesty's Stationery Office, London, 1938. Paper, 9 × 11 in., 161 pp., charts, maps, tables. (Obtainable from British Library of Information, New York, $2.15.) Tabular and explanatory data regarding observations made with deposit gages and automatic filters, measurements of sulphur pollution, daylight, and ultraviolet radiation, including the effect of the site of the station upon recorded observations.

INTRODUCTION TO COLLEGE PHYSICS. By C. M. Kilby. Second edition. D. Van Nostrand Co., New York, 1938. Cloth, 6 × 9 in., 398 pp., illus., diagrams, charts, tables, $3.25. This textbook is intended to present a brief course in the fundamentals of physics. The arrangement of material is orthodox, with five main sections on mechanics, sound, heat, magnetism and electricity, and light. There are many worked-out problems in the text material and lists of review problems with each chapter.

ISAAC NEWTON 1642–1727. By J. W. N. Sullivan, with a memoir of the author by C. Singer. The Macmillan Co., New York, 1938. Cloth, 6 × 9 in., 275 pp., $2.50. A new biography in which the purpose has been to paint a clear picture of Newton, the man, stressing the events which influenced his career nd throw light on his character. His scientific achievements are discussed particularly with reference to their relation to the contemporary scene and subsequent developments.

I S-TAFEL FÜR LUFT UND VERBRENNUNGSGASE. By O. Lutz and F. Wolf. Julius Springer, Berlin, 1938. Paper, 8 × 11 in., 14 pp., charts, tables, 3 rm. A heat-content-entropy chart for air and combustion gases. The accompanying text covers the range, description, and use of the diagram, the fundamentals of the calculations, the corrections to be applied, and an example of practical application.

KENT'S MECHANICAL ENGINEERS' HANDBOOK. Design, Shop Practice. (Wiley Engineering Handbook Series, Vol. 3.) Eleventh edition, by R. T. Kent, 1938. Leather, 6 × 9 in., 1378 pp., diagrams, charts, tables, $5. The second volume of the revised "Kent" is intended to meet the needs of mechanical engineers interested in machine design and manufacture. Detailed practical information is provided upon all the variety of subjects which fall in this field, such as the properties of materials and machine elements, vibration, buildings, heating processes, forging and foundry practice, machining and woodworking, the handling of materials, power transmission, safety engineering, etc. The editor has been assisted by many collaborators. The work has been practically rewritten and reset in a larger format. It is a distinctly valuable addition to the reference library of the mechanical engineer.

KORROSIONEN AN EISEN UND NICHTEISENMETALLEN. By A. Siegel. J. Springer, Berlin, 1938. Cloth, 8 × 11 in., 86 pp., illus., diagrams, charts, tables, 21.60 rm; paper 19.50 rm. This work discusses the phenomenon of the pitting of iron and nonferrous metals and is based upon experience in electric power plants and on ships. The nature and causes of corrosion are first discussed, together with the influence of structure and hardness upon resistance to it. Electrolytic corrosion phenomena in electric power plants, centrifugal pumps, surface condensers, oil coolers, and bearings are described. Alternating-current and direct-current corrosion are compared. Other matters treated are chemical injuries to surface condensers, electrolytic corrosion on ships, and the causes of corrosion of steam-turbine blades.

DIE KORROSION VON NICHTEISENMETALLEN UND DEREN LEGIERUNGEN. (Die Korrosion Metallischer Werkstoffe, Bd. 2.) Edited by O. Kröhnke and G. Masing. S. Hirzel, Leipzig, 1938. Paper and bound, 7 × 10 in., 901 pp., illus., diagrams, charts, tables; paper, 66.50 rm; bound, 69 rm. The second volume of this monograph on corrosion is concerned with nonferrous metals and alloys. The opening section discusses methods for the investigation of corrosion. Succeeding sections afford a detailed and comprehensive survey of the corrosion of the various metals and their alloys. The major part of the volume is devoted to the most used metals, copper, lead, tin, zinc, and nickel. Briefer consideration is given to tungsten, molybdenum, chromium, cadmium, and the precious metals. The two volumes form a very useful review of our knowledge of corrosion.

ALFRED KRUPP und sein Geschlecht—150 Jahre Krupp-Geschichte, 1787–1937. By W. Berdrow. Paul Schmidt, Berlin, Verlag für Sozialpolitik, Wirtschaft und Statistik, 1937. Cloth, 7 × 10 in., 229 pp., illus., diagrams, 2.50 rm.

THE KRUPPS—150 Years Krupp History, 1787–1937, by W. Berdrow, translated by F. Homann, same publisher as foregoing, 1937. Cloth, 5 × 8 in., 326 pp., illus., 8 rm. While the first book is a history of the Krupp family through the period from 1787 to 1937 four fifths of the volume is devoted to Alfred Krupp, who was actively the head of the family steel business from 1826 until 1887. The story is based upon family documents and business archives and gives special attention to the personalities involved and the difficulties which beset the steel works in its early days. The second book, which is a translation of the first, lacks many of the illustrations which the original German volume contains.

A MANUAL OF PORCELAIN ENAMELING. Edited by J. E. Hansen; Enamelist Publishing Company, Cleveland, Ohio, 1937. Leather, 6 × 9 in., 513 pp., illus., diagrams, charts, tables, $5. A collection of articles upon the application of wet-process enamels to sheet iron and cast iron. A diversity of subjects is covered, including design and fabrication of sheet-iron parts, equipment and methods for preparing and applying enamels, inspection, and decorative effects. Short bibliographies and a glossary add to the value of the book.

MARKET CONTROL IN THE ALUMINUM INDUSTRY. By D. H. Wallace. Harvard University Press, Cambridge, 1937. Cloth, 6 × 9 in., 599 pp., tables, $5. A searching examination of the aluminum industry from the economic viewpoint. The historical background of the industry is given, the reasons for the virtual monopoly existing in the United States are explained, the fluctuation between competitive and combined action in Europe is examined, and the probable results of diverse methods of control are evaluated.

MECHANICS OF MACHINERY. By C. W. Ham and E. J. Crane. Second edition. McGraw-Hill Book Co., New York and London, 1938. Cloth, 6 × 9 in., 476 pp., diagrams, charts, tables, $4. Such fundamental mechanisms as linkages, cams, gears, etc., are described and design calculations are explained in Part I. Part II covers the kinematics and dynamics of machinery, includes velocities, accelerations, static forces and inertia forces in machines, the balancing of machinery, and the force analysis of a gasoline engine. There is a section of problems. This edition has been entirely reset and thoroughly revised.

A MODERN SPANISH-ENGLISH AND ENGLISH-SPANISH TECHNICAL AND ENGINEERING DICTIONARY. By R. L. Guinle. E. P. Dutton & Co., New York, 1938. Cloth, 6 × 10 in., 311 pp., $4. There are relatively few dictionaries of Spanish and English technical terms, and still fewer that have been revised recently. As a result, any modern one is a useful addition. This one is a well-printed volume of convenient size, the work of an English engineer with long experience in South America. The vocabulary covers the terms used in civil, mechanical, and electrical engineering.

NATIONAL PHYSICAL LABORATORY REPORT for the year 1937. His Majesty's Stationery Office, London, 1938. Paper, 6 × 10 in., 150 pp., tables, 2s 6d. (Obtainable from British

Library of Information, New York, $0.80.) In addition to general information concerning the laboratory and its work, this publication presents the reports of the William Froude Naval Laboratory and the departments of physics, electricity, radio, metrology, engineering, metallurgy, and aerodynamics, indicating the state of the current researches.

PORTRAITS OF THE IRON HORSE, the American Locomotive in Pictures and Story. By O. Kuhler and R. S. Henry. Rand McNally & Co., Chicago, 1937. Cloth, 9 × 11 in., 80 pp., illus., $2. Steam-locomotive history in America from the earliest attempts to the modern streamlined forms. A concise description of types and equipment, and of the development to meet progressive needs, together with some technical and statistical information; illustrated by page drawings of special locomotives or types and small sketches for the graphic depiction of technical points.

Practical Treatise on CHIMNEY DESIGN. By D. A. Molitor. Peters Co., Detroit, Mich., 1938. Paper, mimeographed, 7 × 9 in., 123 pp., tables, diagrams, charts, $2.50. A comprehensive treatise on the structural stability and practical design of chimneys. General factors relating to selection of types and materials, theoretical stress analysis, and chimney foundations are covered in the first few chapters. Then follow three chapters treating respectively of brick, reinforced concrete, and steel types. Comparative design data and costs are given for corresponding chimneys in the three materials. Chimney builders are listed.

REPORTS ON PROGRESS IN PHYSICS, vol. 4, edited by A. Ferguson. University Press, Cambridge, England; Physical Society, London, 1938. Leather, 7 × 10 in., 389 pp., diagrams, charts, tables, $5. This excellent series, issued under the auspices of the Physical Society, provides an annual survey of advances in physical science. The present volume is as of the end of 1936. It includes reviews of the work in heat, spectroscopy, sound, experimental electricity and magnetism, the charge of the electron, and atomic physics. More comprehensive articles are included upon the measurement of time, the adsorption of gases by solids, surface tension, supersonics in relation to molecular constitution, thermodynamics, refrigeration, the beginnings of the new quantum theory, slow neutrons, electrolytes and electrolysis, physico-optical instruments and materials, X-ray analysis and application of Fourier-series methods to molecular structures, and diamagnetic and paramagnetic anisotropy of crystals. Each article is the work of a specialist.

ROYAL TECHNICAL COLLEGE JOURNAL, Vol. 4, Part 2, January, 1938. Royal Technical College, Glasgow. Paper, 7 × 10 in., pp. 213–420, illus., diagrams, charts, tables, 10s 6d. This publication presents the results of recent research work carried out in the Royal College, Glasgow. Among the matters investigated were the vibrations of a rifle barrel, the determination of the viscosities of slag systems, accelerated tests of strengths of cement products, deflection phenomena in a fixed beam under impact, mechanical properties of a welded joint, wind pressures upon an open tank, the mechanism of wear in metals, and the design of interphase transformers.

S.A.E. HANDBOOK, 1938 edition. Society of Automotive Engineers, New York. Leather, 6 × 9 in., 776 pp., illus., diagrams, charts, tables, $5. This edition, revised to January, 1938, contains all the current standards and recommended practices of the Society of Automotive Engineers concerning automobile and aircraft materials and parts. Forty-five changes from the 1937 edition are noted.

SEVENTY YEARS OF THE WORCESTER POLYTECHNIC INSTITUTE. By H. F. Taylor. Worcester Polytechnic Institute, Worcester, Mass., 1937. Cloth, 6 × 9 in., 415 pp., illus., diagrams, $2. A historical account of the founding and development of the Worcester Polytechnic Institute, containing information concerning persons, policies, activities, courses of instruction, and other matters, both as items of intrinsic interest and as contributory factors toward its present state.

SCHWINGUNGEN IN DEN ZULEITUNGS- UND ABLEITUNGSKANÄLEN VON WASSERKRAFTANLAGEN. By J. Frank and J. Schüller. Julius Springer, Berlin, 1938. Cloth and unbound, 6 × 10 in., 200 pp., diagrams, charts, tables; cloth, 28.80 rm.; unbound, 27 rm. A treatise on the fluctuations in hydraulic power-plant channels. The investigation of wave phenomena in open channels covers propagation and wave form and the mathematical handling of varying conditions in the head-water channel and the tailrace. The latter half of the book is devoted mainly to the mathematical determination of vibration amplitudes in surge tanks and pressure tunnels.

SELECT BIBLIOGRAPHY ON THE LOCATION OF INDUSTRY. (Social Research Bulletin No. 2). By D. M. McDonald. McGill University, Montreal, Can., 1937. Paper, 7 × 10 in., 84 pp., $.60 + $.10 postage. A list of some 700 references to books, reports, and magazine articles grouped under four heads: General references; industrial location; industrial and economic surveys; statistical, bibliographical, and other sources. There is an alphabetical list of authors and a similar list of magazines from which articles have been indexed.

STEEL SQUARE POCKET BOOK. By D. L. Stoddard. Fifth edition, revised. Scientific Book Corporation, New York, 1937. Leather, 4 × 6 in., 181 pp., diagrams, charts, tables, $1. Practical methods of using the carpenter's steel square for all sorts of measurement, layout, and framing problems. The information is of such form as to be directly applicable to the job at hand.

TAFELN ÜBER ABKÜHLUNGSVORGÄNGE EINFACHER KÖRPER. By H. Bachmann. Julius Springer, Berlin, 1938. Paper, 7 × 10 in., 8 pp., diagrams, charts, tables, 4.80 rm. This set of graphs is intended to simplify the calculation of the regular cooling and heating of bodies. Charts are provided for the cooling of plates, cylinders, and spheres, from which the temperatures at the mid-point and on the surface, and the heat loss from the body, can be obtained with sufficient accuracy for practical purposes.

TEXTBOOK OF CONVERGENCE. By W. L. Ferrar. Clarendon Press, Oxford, England; Oxford University Press, New York, 1938. Cloth, 6 × 9 in., 192 pp., diagrams, tables, $3.50. A mathematical treatise on convergence presenting the information concerning that theory necessary for a university course in pure and applied mathematics. The mathematical properties and manipulations of sequences and series are explained to provide the proper knowledge of the fundamental ideas, definitions, and theorems.

TRANE AIR CONDITIONING MANUAL. Second edition. The Trane Co., La Crosse, Wisconsin, 1938. Cloth, 8 × 11 in., 333 pp., illus., diagrams, charts, tables, $5. Primarily concerned with the application of the fundamental facts of engineering to the design of air-conditioning systems, this publication touches on all phases of the field. Heat and its transmission, physical comfort, air properties and supply, psychrometry, refrigeration and ventilation processes, and the functions of water in air conditioning, all these, with numerous diagrams, tables, problems, and numerical examples, comprise a comprehensive practical treatment of the subject.

V.D.I-FORSCHUNGSHEFT 389. Einfluss der Querschnittsverformung auf die Entwicklung der Geschwindigkeits- und Druckverteilung bei turbulenten Strömungen in Rohren. By E. Mayer. V.D.I. Verlag, Berlin, 1938. Paper, 8 × 12 in., 20 pp., diagrams, charts, tables, 5 rm. A discussion of the influence of cross-section form on the evolution of velocity and pressure distribution in turbulent flow in tubes. The setup, equipment, and method of investigation are described, and the findings of the research are given and summarized.

DAS VERSUCHS- UND MESSWESEN AUF DEM GEBIET DES KRAFTFAHRZEUGS. By W. Kamm and C. Schmid. J. Springer, Berlin, 1938. Cloth, 8 × 11 in., 312 pp., illus., diagrams, charts, tables, 49.80 rm. This volume, intended as a manual for automobile research laboratories, is based upon the experience of the Automobile Research Institute of the Stuttgart Technical High School and contains detailed descriptions of methods and apparatus. Methods for engine testing include the testing of fuels and lubricants and measurement of fuel consumption, air intake, engine efficiency, cooling and temperature, and the investigation of combustion, exhaust gases, etc. Methods are also given for investigating such characteristics of the automobile as speed, wind resistance, brakes, springs, steering, driving ease, and noisiness. A chapter discusses model tests. A list of several hundred references is appended.

WÄRMETECHNISCHE RICHTWERTE, edited by F. Henning. V.D.I. Verlag, Berlin, 1938. Leather, 6 × 9 in., 106 pp., tables, 10 rm. This collection of tables, which has been prepared by direction of the Physikalisch-Technische Reichsanstalt, is intended as a collection of the most reliable values for various physical and chemical constants. In addition to some general tables of physical constants and conversion tables, it contains a fairly complete collection of tables for temperature measurement and of data upon thermal properties of solids and liquids. Other tables show the properties of water and steam, thermal expansions, viscosities, specific heats, conductivities, heats of reaction, etc.

(ADKI) WERKSTATTGERECHTES KONSTRUIEREN, Heft 5: GESENKSCHMIEDEN. Regeln und Beispiele für den Konstrukteur. V.D.I. Verlag, Berlin, 1938. Paper, 8 × 12 in., 28 pp., illus., diagrams, charts, tables, 4.50 rm. This pamphlet is intended to assist the designer of work which is to be drop-forged or swaged, by supplying a brief summary of the data which are necessary for correct interpretation of the drawings in the shop. The selection of shapes, forging methods, tolerances, operations, materials, and testing are discussed.

Werkstoffhandbuch NICHTEISENMETALLE: Abschnitte A bis C, edited by Deutsche Gesellschaft für Metallkunde im Verein deutscher Ingenieure. V.D.I. Verlag, Berlin, 1938. Paper, 6 × 9 in., 178 pp., illus., diagrams, charts, tables, 15 rm. A revised edition of the first three parts of the nonferrous metals section of the V.D.I. materials handbook. Part A contains general physical and structural theory; part B covers the mechanical and technological testing of metals; part C covers the physical, chemical, and structural testing of metals. Each part is composed of articles by various men describing specific procedures or equipment.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Program for A.S.M.E. Fall Meeting at Providence, R. I., Oct. 5–7

Symposiums on Rubber and Jewelry Manufacture With Sessions on Fuel and Power, Machine-Shop Practice, Textiles, Management, Iron and Steel

TECHNICAL sessions and plant visits planned to take advantage of the many opportunities afforded by the distinctive and diversified nature of the program to be offered by the industries of Rhode Island, are the principal features of the A.S.M.E. Fall Meeting in Providence, R. I., October 5 to 7, with headquarters at the Providence-Biltmore Hotel.

Fuels and power, machine-shop practice, textiles, management, iron and steel, rubber are all represented on the technical program which has been made public by the Society's Committee in charge of the Meeting.

Jewelry Symposium

One session, which, it is felt, will be of unusual interest, is a "Jewelry Symposium" at which five papers will deal comprehensively with the problems of that industry. This particular session is peculiarly appropriate for a Providence meeting since it is said that three fourths of the employees engaged in the jewelry-manufacturing industry in the United States are employed within a radius of twenty miles from Providence. The distinguishing feature of this industry lies in the fact that it is made up of numerous small companies, each of which is engaged in a highly specialized line. In view of current interest in the decentralization of industry, a discussion of the management problems in the manufacture of jewelry seems most appropriate.

Courtesy, Providence Chamber of Commerce

JOHN BROWN HOUSE

(Built in 1786 it was described by President John Quincy Adams as "the most magnificent and elegant private mansion that I have ever seen on this continent.")

Rubber Symposium

The increasing importance of rubber in engineering is emphasized by the symposium on rubber. The papers which are listed by title in the program in this issue will high light the important features of production and use. Sufficient background will be presented to establish the significance of all new material in the papers. It is expected that there will be adequate attendance from the rubber companies to provide well-balanced discussion.

The Committee on Rubber and Plastics which is sponsoring this symposium will meet in the Providence-Biltmore on the evening of October 5 to discuss projects for 1939 and 1940 and any members of the Society who may desire to take part in the Committee's activities will be most welcome.

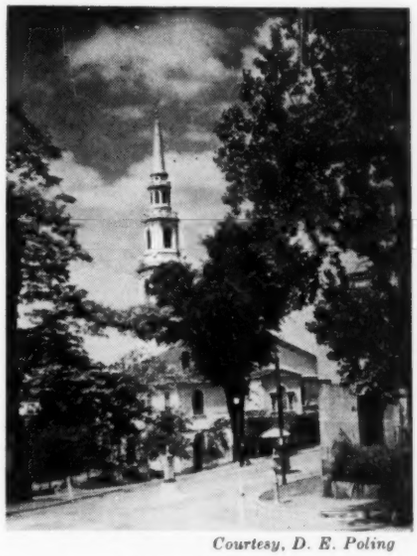
Plant Visits

As was outlined in more detail in the August issue, the plant-visit program is an extensive one. Many firms are to make the A.S.M.E. members welcome and open house is to be the order of the day. Trips are all being so arranged that no technical sessions will have to be passed up to see a favored factory.

The Committee wants it emphasized that the women in attendance at the Meeting will be most welcome on all plant-inspection trips.

Providence

Probably no more interesting city in the United States could have been chosen for the A.S.M.E. Fall Meeting than Providence, R. I. Founded by Roger Williams in 1636 as a "shelter for persons Distressed for Conscience" it established a principle of freedom of thought



Courtesy, D. E. Poling

FIRST BAPTIST MEETING HOUSE

(Congregation founded in 1639 by Roger Williams. Built in 1775 for the "worship of God and to hold Commencements in." The spire designed in the Christopher Wrenn style is one of the finest in the country.)

in intellectual and "religious concernments' that proved to be one of the greatest factors in influencing the course of human progress.

Providence early attracted mills, factories, shipyards, and sailing vessels, which made it one of the greatest industrial cities of the colonies. Today the city embraces some of the largest manufacturing establishments in the world.

Program

WEDNESDAY, OCTOBER 5

9:30 a.m.

Fuels

High Pressure Installation at L Street Station, So. Boston, by Geo. A. Orrok, Jr.

Discharge Temperatures From Pulverizers, by Ollison Craig

Machine Shop Practice

Recent Development in Thread Grinding Practice, by Paul V. Miller

The Refinement of Ground Surfaces, by Herbert S. Indge

Rubber

The History of Rubber as an Engineering Material, by W. C. Geer

Synthetic Substances With Rubber-Like Properties, by Ernest R. Bridgwater

(Program continued on page 716)

2:00 p.m.

Machine Shop Practice

Accuracy of Borizing, by Carl T. Guething
Gear Loading, by W. P. Schmitter

Rubber

Problems in the Fabrication of Rubber Products, by E. G. Kimmich
The Mechanical Characteristics of Rubber, by Fred L. Haushalter

8:00 p.m.

Jewelry Symposium

The Origin and Growth of the Industry to Date, by Edward O. Otis, Jr.
The Search for Consumer Preference, by Lawrence E. Baer
The Production Problems of the Industry, by Frederick A. Ballou, Jr.
The Problem of Syndicate Store Production
Distribution Methods of the Medium- and Low-Priced Jewelry Manufacturing Industry, by Harold E. Sweet

Fuels

Industrial Power-Plant Steam and Power Generation, R. D. Booth
The Atomization of Oil by Small Pressure Atomizing Nozzles, by E. B. Glendenning, L. H. Ventres, W. A. Sullivan, and A. R. Black

Industrial Instruments and Apparatus

Application of an Asymptotic Reset Controller to Sewage Clarification, by R. P. Lowe

THURSDAY, OCTOBER 6

9:30 a.m.

Machine Shop Practice

How Useful Is Your Sense of Proportion, by W. E. Johnson
Motor Drives and Electric Controls on Machine Tools, by Benjamin P. Graves

Power

Condenser-Tube Life Vs. Design and Mechanical Features of Operation, by A. J. German
Condenser Performance With Reduced Cooling Surface, by J. H. Harlow and R. A. Bowman
Control of Slime and Algae in Industrial Cooling Waters, by H. K. Nason and J. D. Fleming

Textile

Worsted System Spinning, Including the Spinning of Rayon Fibers, by Geo. F. Bliss

12:30 p.m.

Textile Luncheon

Merchandising of Spun-Rayon Fabrics, by S. J. Kennedy

2:00 p.m.

Textile

Weaving, by Albert Palmer
The Development of the Shearing of Textile Fabrics, by Ralph L. Marble

2:00 p.m.

Plant Visits

6:30 p.m.

Clambake at Pomham Club

FRIDAY, OCTOBER 7

9:30 a.m.

Management

Control of Purchases in a Small Plant, by W. C. Zinck
Industry, Labor, and the Public, by Ray M. Hudson

Iron and Steel

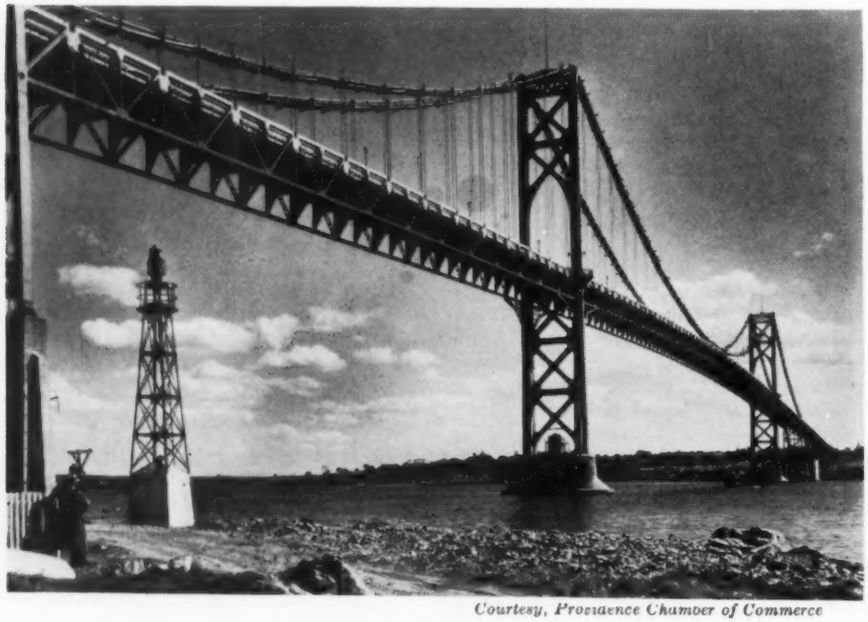
Magnaflux Inspection Applied to Aircraft-Engine Parts, by H. J. Noble
Recent Developments in Powder Metallurgy, by Gregory J. Comstock

Power

Industrial-Evaporator Design, Application, and Operation, by W. K. Adkins
Industrial Applications of Evaporators in No. 1 Power House of the Ford Motor Co., by W. W. Dulmage

2:00 p.m.

Plant Visits



Courtesy, Providence Chamber of Commerce

MOUNT HOPE BRIDGE

(This suspension bridge connects Mount Hope with Rhode Island and will be remembered as the one where the individual strands of the cable began to fail upon loading and had to be dismantled and rebuilt.)

A.S.M.E. Forms Committee on Rubber and Plastics

SINCE rubber and plastics have attained such an important position in industry, The American Society of Mechanical Engineers recently established a Committee on Rubber and Plastics which will deal with several phases of the rubber and plastics industries, including mechanical applications, research on basic mechanical properties, processing equipment, and standards.

The Committee will also sponsor the presentation of papers at technical sessions of the national meetings of the Society. A symposium on rubber, comprising four papers covering the history of rubber, synthetic substances with rubber-like properties, fabrication of rubber parts, and certain mechanical properties of rubber, is included in the Providence meeting, the program of which appears on pages 715 and 716 of this issue.

Dr. F. L. Yerzley, E. I. du Pont de Nemours & Co., Inc., is chairman of the new committee, and Dr. J. F. Smith, Edward G. Budd Manufacturing Co., is secretary.

Committee Members Visit Local Sections

D. B. Prentice Covers New England; W. R. Woolrich Visits Midwest, South, West

MEETING in St. Louis last June, the Committee on Local Sections decided that instead of meeting in Providence in October, the members of the Committee would visit as many local sections as possible to gain first-hand information concerning their problems.

Starting in Tulsa, Oklahoma, on July 22, W. R. Woolrich, chairman of the Committee, visited the following local sections: Mid-Continent, Kansas City, Nebraska, Tri-Cities, Peoria, Rock River Valley, Minnesota, Central Indiana, St. Joseph Valley, Columbus, Cincinnati, Knoxville, Chattanooga, Atlanta, Birmingham, New Orleans, and South Texas. During September, Dean Woolrich will meet with the Colorado Section on Sept. 1, Utah Section on Sept. 5, Los Angeles on Sept. 7, and San Francisco on Sept. 8.

Because of summer vacations, D. B. Prentice

in his tour of the New England Local Sections talked mainly with the old and new officers about their problems. Mr. Prentice was well pleased with the active program in most of the sections and liked the junior group work in the sections where the number of junior members make such activity feasible. The Local Sections visited by him included Boston, Worcester, Providence, Norwich, New Haven, Bridgeport, Waterbury, New Britain, Hartford, Western Massachusetts, and Green Mountain.

Railroad Division Starts News Letter

TO ACQUAINT the members of the A.S.M.E. Railroad Division, with the work being done in and outside of the division, a mimeographed monthly news letter has been started, the first issue appearing in June. Marion B. Richardson, secretary of the Division, is the editor. Contributions of short items of interest are solicited and will be received at A.S.M.E. Headquarters in New York.

A.S.M.E. Calendar

of Coming Meetings

September 12–16, 1938

Applied Mechanics and Hydraulic Divisions Cooperating in International Congress of Applied Mechanics
Cambridge, Mass.

September 22–23, 1938

Wood Industries Division Meeting
High Point, N. C.

September 28–30, 1938

Applied Mechanics Division (jointly with the Institute of Aeronautical Sciences)
Los Angeles, Calif.

October 5–7, 1938

Fall Meeting
Providence, R. I.

October 13–15, 1938

Fuels Division Meeting (jointly with A.I.M.E. Coal Division)
Chicago, Ill.

October 18, 1938

Joint Meeting with American Welding Society
Detroit, Mich.

December 5–9, 1938

Annual Meeting
New York, N. Y.

February 23–25, 1939

Spring Meeting
New Orleans, La.

High Point, N. C., Welcomes National Meeting of Wood Industries Division

To Be Held September 22–23 in Cooperation With the Southern Furniture Manufacturers' Association

MEMBERS of the A.S.M.E. Charlotte Section are joining with members of the Wood Industries Division to make their eleventh National Meeting in High Point, N. C., a memorable one.

Known as the "Industrial City of the South," High Point has one hundred and sixty manufacturing plants which include thirty furniture factories and twenty-two hosiery mills. The Southern Furniture Market is visited by thousands of retail furniture dealers each year and in this building nearly 200 furniture and allied exhibits are maintained.

The Southern Furniture Manufacturers' Association will hold its meeting on September 21 while the A.S.M.E. Wood Industries sessions are scheduled for September 22 and 23. It is hoped that members of both organizations will be able to attend both meetings.

SOUTHERN FURNITURE EXPOSITION BUILDING

(Is ten stories high and contains 200,000 square feet of floor space. It houses over 200 exhibitors of furniture and houseware from 28 states.)

Inspection Trips

The detailed program of papers for the Wood Industries Division was published in the August issue of MECHANICAL ENGINEERING on page 653, but at that time the plant-inspection trips were not completely arranged. Now these are scheduled and it is an interesting and worth-while selection of plants that has been made.

The plant of the B. F. Huntley Furniture Company in Winston-Salem, N. C., is well-equipped with modern plant machinery, making merchandise on a quantity basis. Its product is bedroom and dining-room furniture. All operations required in furniture manufacture will be shown during the tour of the plant.

The Marietta Paint and Color Company was one of the first finishing-material manufacturers to establish a plant in High Point. The plant has a well-equipped laboratory which will be open for inspection as will the processes of manufacturing varnish, enamels, stains, etc.

At the Myrtle Desk Company in High Point the operations and processes required to manufacture desks will be shown, while at the Tomlinson plant, where the showrooms are considered among the finest in the industry, all kinds of household as well as institutional furniture will be on view.

At the Statesville Plywood & Veneer Company, Statesville, N. C., the operations will follow the entire cycle of manufacture from the cutting of veneer on rotary lathes to the final bonding of the veneer into plywood on a newly installed hot-plate press with waterproof resin adhesive. The intermediate steps will afford a much clearer view of the advantages of plywood construction.

Women Will Be Welcomed on Trips

There will be much in these trips to interest the women in attendance at the meeting and it is hoped that there will be many who will accompany the men in the family to High Point situated in a smiling countryside dotted with prosperous farms.

Headquarters will be at the Sheraton Hotel and members are urged to write directly to the Hotel and make room reservations just as soon as possible.

Joint Fuels Session in Chicago, Oct. 13–15

RECENT developments in the production and preparation of coal for industrial and home use will be the subject of the jointly sponsored Fuels Meeting of the Fuels Division, A.S.M.E., the Coal Division, A.I.M.E., and the Western Society of Engineers, in Chicago, Oct. 13–15, 1938. Cooperating will be the Illinois and the Indiana Mining Institutes.

According to preliminary announcements, the first two days of the meeting will be devoted to general technical sessions with special interest sessions being held simultaneously on Friday afternoon. That evening, a dinner will be held with Dr. W. L. Abbott, member, A.S.M.E., as toastmaster and Howard N. Eavenson as principal speaker.

Members of the A.S.M.E. on the general committee include R. E. Turner, vice-chairman, C. C. Austin, H. M. Black, L. M. Ellison, H. F. Hebley, F. B. Orr, and Daniel Roesch.

A.S.M.E. Members Are Honored

Medals and Degrees Bestowed Upon Durand, Davis, Hirshfeld, and Others

MEDALS and doctors' degrees were presented to several members of The American Society of Mechanical Engineers during the June commencement exercises of colleges throughout the land and at the meetings of several societies.

The honorary degree of doctor of engineering was conferred on June 17 by Worcester Polytechnic Institute on William F. Durand, past-president of the Society, and on Frederick M. Feiker, executive secretary of the American Engineering Council. A photograph of the recipients appears on this page.

At the commencement exercises of Rose Polytechnic Institute on June 4, the address was presented by Harvey N. Davis, President of the Society, who was given an honorary degree of doctor of engineering on the occasion.

The Society for the Promotion of Engineering Education on June 29 presented its Lamme Medal for achievement to Robert L. Sackett, past vice-president of the Society. The citation and Dean Sackett's photograph appear in another column on this page.

At Tulane University, a plaque commemorating the retirement of William B. Gregory, professor of experimental engineering and hydraulics and for 44 years a member of the faculty, was presented to the college by members of the graduating class on June 16. It will be hung in the engineering building.

C. F. Hirshfeld, past vice-president of the Society, received the honorary degree of doctor of engineering from the University of Detroit, in recognition of his technical and scientific accomplishments in the field of engineering and in engineering education.

The Ohio State University Lamme Medal "for meritorious achievement in engineering" was presented at the commencement exercises of the University to Professor Emeritus James E. Boyd, for 28 years chairman of the department of mechanics.

The doctorate of science was conferred at its two hundred and eighty-seventh commencement by Harvard University on Irving Langmuir, associate director of the laboratories of the General Electric Company at Schenectady, N. Y.

The doctorate of science was conferred by both Columbia University and Rutgers University on Gano Dunn for "achievement in electrical engineering."

Henry L. Doherty was awarded the honorary degree of doctor of science at the University of Miami on Memorial Day for his work on the prevention of waste of petroleum and his contributions to the scientific and engineering world.

At the commencement exercises on June 11 of the Stevens Institute of Technology, the honorary degree of doctor of engineering was conferred on Robert C. Post and an honorary degree of mechanical engineer was presented to Andrew M. Lockett.

The Marston Medal, an honor conferred upon an engineering alumnus of Iowa State College in recognition of achievement in engineering, was awarded to Earl O. Shreve, vice-president of the General Electric Co., at the commencement exercises on June 13.

RECEIVE HONORARY DEGREES AT WORCESTER POLYTECHNIC INSTITUTE

(From left to right: F. M. Feiker, Mem. A.S.M.E., executive secretary of the American Engineering Council; A. D. Butterfield; Worcester alumus and professor of geodesy at the University of Vermont; W. F. Durrand, honorary member and past-president, A.S.M.E.; A. W. French, for thirty-nine years professor of civil engineering at Worcester; and Ralph Earle, Mem. A.S.M.E., president of Worcester.)

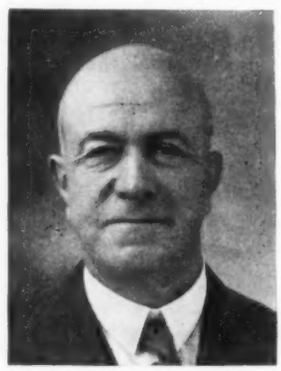
S.P.E.E. Meeting in Texas Attended by More Than 900

Lamme Medal to Dean Sackett; Haney Heads M. E. Division

THE 46TH Annual Meeting of The Society for the Promotion of Engineering Education held at College Station, June 27–30, under the sponsorship of the engineering faculty of the Agriculture and Mechanical College of Texas, was a great success, as attested by the attendance of more than 900 engineering educators from all parts of the United States. At the general sessions which were dedicated to the "Cultural and Professional Phases of Engineering Education," some fifteen addresses and discussions were presented.

The principal event of the meeting was the dinner at which the Lamme Medal for achievement in engineering education was presented to Robert Lemuel Sackett, fellow and past-member of Council of the A.S.M.E. Dean Sackett received the award for his work in coordinating the thoughts of industry and education, for his conception of industrial engineering as a curriculum, for his work in engineering extension and for his own example of tireless effort in behalf of the engineering profession. As the guest speaker at the dinner, Dr. Karl T. Compton, member, A.S.M.E., talked on the accrediting program of the S.P.E.E.

The Mechanical Engineering Division held three sessions during the Meeting under the chairmanship of Prof. Frank L. Eidmann, member, A.S.M.E., Prof. Jiles W. Haney, member, A.S.M.E., was elected chairman of the division for the coming year. Newly elected officers of the Society are: Karl T. Compton, member, A.S.M.E., president; George W. Case and M. L. Enger, vice-presidents; F. L. Bishop, secretary; W. O. Wiley, associate, A.S.M.E., treasurer; and Nell McKenry, assistant secretary. The new Council members are H. H. Armsby, H. T. Heald, Louis Mitchell, C. A. Mockmore, W. B. Plank, J. S. Thompson and R. B. Wiley.



R. L. SACKETT

A.S.M.E. Represented at Mathematical Meeting

UPON the invitation to be represented at the semicentennial celebration of the founding of The American Mathematical Society to be held at Columbia University, Sept. 6–9, 1938, Prof. J. Ormondroyd, University of Michigan, and R. P. Kroon, Western Electric & Mfg. Co., were appointed to represent the A.S.M.E.

Fifth International Congress for Applied Mechanics at Cambridge, Sept. 12–16

A.S.M.E. Applied Mechanics Division Cooperates With Harvard and M.I.T., Who Are Joint Sponsors

THE PROGRAM for the Fifth International Congress for Applied Mechanics to be held at Cambridge, Mass., Sept. 12–16, calls for six general lectures by invitation, a turbulence symposium, and about a hundred communications from members, together with evening entertainments for members and their ladies in accordance with the following schedule:

Monday, Sept. 12

Registration at M.I.T. and assignment to rooms at Harvard. Opening of Congress at 1:45 p.m. General lecture by H. U. Sverdrup of the University of Bergen, Norway, and the University of California, on "Ocean Circulation." General lecture by C. H. Chatfield, United Aircraft Corporation, on "Aeronautics." Dedication of Wright Brothers Memorial Wind Tunnel at 4:30 p.m. At 8:30 in the evening, a reception by President and Mrs. Karl T. Compton to members and ladies.

Tuesday, Sept. 13

In the morning, a turbulence symposium under the leadership of L. Prandtl of Gottingen University. Technical sessions will be held simultaneously. General lecture by G. I. Taylor of the Royal Society of Great Britain, on "Turbulence." In the afternoon, the turbulence symposium and the technical sessions will be continued. In the evening, a conversazione will be held in the M.I.T. laboratories for members and ladies.

Wednesday, Sept. 14

In the morning, simultaneous technical sessions will be followed by a general lecture by F. Koerber of Dusseldorf, on "Metals." The technical sessions will be continued during the afternoon. Following a meeting of the International Congress Committee, a dinner for the Committee and their guests will be held by President Compton. Later, a reception at The Isabella Stewart Gardner Museum will take place.

Thursday, Sept. 15

Simultaneous technical sessions in the morning followed by a general lecture by J. Peres of the University of Paris, on "Analogue Methods." In the afternoon, a motor trip will be made through Lexington and Concord by the members and their ladies as guests of the Cambridge Committee.

Friday, Sept. 16

Simultaneous technical sessions in the morning followed by a general lecture by Hardy Cross of Yale University, on "Structures." The technical sessions will continue through the afternoon. The concluding affair of the Congress will be the dinner in the evening at Eliot House, Harvard University, for members and ladies, with those from overseas being guests of the Cambridge Committee.

Additional information about the Congress may be obtained through A.S.M.E. Headquarters or directly from J. C. Hunsaker or Th. von Kármán, M.I.T., Cambridge, Mass.

Welcome Awaits A.S.M.E. Members in Cuba

ENTERTAINMENT of visiting engineers is one of the functions of the Association of American Engineers in Cuba, a group embracing engineers in all fields, according to a communication received from H. Craig Sutton, who has just been elected president of the Association. He asks that any member of the Society intending to visit Cuba write to him at Compania Cubana de Electricidad, Apartado 1715, Habana, Cuba.

Student Branch Secretaries

Please Note!

REPORTS of meetings and inspection trips must be received at Society Headquarters on or before the sixth of the month in order to appear in next month's issue of MECHANICAL ENGINEERING. Example: All copy received up to Sept. 6 will be in the October issue, etc.

PHOTOGRAPHS of student member groups are always welcome for use in MECHANICAL ENGINEERING. Prints should be preferably glossy and of good contrast. However, send in everything you have and the editorial department will use those it can reproduce.

PUBLICITY is always good for the branch. Clippings from school and local newspapers should be sent in with your reports.

Seventh International Management Congress Meets in Washington, D. C., Sept. 19–23

Invitation Extended to A.S.M.E. Members to Attend and to Participate in Congress

MORE than two hundred papers on a wide range of subjects relating to administration, production, distribution, personnel, agriculture, and the home, will be presented at the five-day series of general and technical sessions of the Seventh International Management Congress in Washington, D. C., Sept. 19–23. The comprehensive program of activities has resulted from months of planning by many leading executives and engineers of American business organizations to develop the two official themes of the Congress—"recent developments in management" and "economic and social aspects of management."

In this triennial meeting of world experts in the field of management, the leaders of the Congress believe that there is afforded the finest opportunity in a decade for the consideration of those fundamental problems which should be the main concern of management—its opportunities, responsibilities, relationships, techniques, and practices. Membership in the Congress is open to anyone interested in the problems of management upon payment of a registration fee of ten dollars which entitles the registrant to attend all sessions and to receive the proceedings of the Congress in seven volumes, six prior to the Congress and one later.

Further information may be obtained through the headquarters of the A.S.M.E., or directly from N. W. Barnes, executive secretary, Seventh International Management Congress, 347 Madison Avenue, New York City.

Program of General Sessions

Monday, Sept. 19, 11:00 a.m.

Presiding: WILLIS H. BOOTH, *Honorary Chairman*, Seventh International Management Congress

Message of Welcome, Cordell Hull, Secretary of State, U. S. A.

Responses—Lord Leverhulme, *President*, International Committee of Scientific Management, and representatives of foreign delegations

Monday, Sept. 19, 2:30 p.m.

Presiding: W. Averell Harriman, Brown Brothers, Harriman & Co.

Management's Responsibilities to Society, A. W. Robertson, *Chairman*, Westinghouse Electric & Manufacturing Company

Development of the Management Movement—A Review and an Interpretation, Harry Arthur Hopf, *Deputy President*, International Committee of Scientific Management; *Senior Partner*, H. A. Hopf & Company

Tuesday, Sept. 20, 12:15 (Luncheon)

Presiding: Harvey N. Davis, *President*, The American Society of Mechanical Engineers; *President*, Stevens Institute of Technology

Psychological Foundations of Management, Henry C. Link

Human Aspects of Management, Maurice

Ponthiere, Directeur de l'Ecole d'Organisation Scientifique du Travail de Paris

Tuesday, Sept. 20, 8:00 p.m.

Presiding: C. S. Ching, *Director of Industrial and Public Relations*, U. S. Rubber Products, Inc.

A Common Ground for Labor and Management:
- (a) Labor's Aims and Responsibilities, Robert J. Watt, American Workers' Delegate to International Labor Office
- (b) Management's Aims and Responsibilities, Lewis H. Brown, *President*, Johns-Manville Corporation
- (c) The Public's Concern in Industrial Harmony, William Allen White, *Editor*, "The Emporia Gazette"

The Machinery for Industrial Conciliation and Arbitration in Great Britain, R. Lloyd Roberts, *Chief Labor Officer*, Imperial Chemical Industries, Ltd., London

Wednesday, Sept. 21, 12:15 (Luncheon)

Presiding: Leverett S. Lyon, *Executive Vice-President*, Brookings Institution

Influence of Technical Progress Upon Social Development, Karl T. Compton, *President*, Massachusetts Institute of Technology

The Social Aspects of Scientific Management, G. Seebauer, *Director*, Reichskuratorium fuer Wirtschaftlichkeit (Germany)

Thursday, Sept. 22, 12:15 (Luncheon)

Presiding: Charles R. Hook, *President*, American Rolling Mill Company; *President*, National Association of Manufacturers

The Continuance of Free Enterprise, W. J. Cameron, Ford Motor Company; A. Basch, *General Manager*, United Chemical & Metallurgical Works, Prague, Czechoslovakia

Thursday, Sept. 22, 2:30 p.m.

Presiding: Clarence Francis, *President*, General Foods Corporation

Reshaping Distribution to Modern Economy, Oswald W. Knauth, *President*, Associated Dry Goods Corporation of New York

Coordination of Production and Distribution, Nils A. Sterner, *General Manager*, Telefonaktiebolaget L. M. Ericssons, Stockholm, Sweden

The Balancing of Incentive and Security, Ralph E. Flanders, *President*, Jones and Lamson Machine Company

Employee Security as a Responsibility of the State, Gino Olivetti, *Chairman*, Enios, Rome, Italy

Thursday, Sept. 22, 8:00 p.m. (Banquet)

Presiding: William L. Batt, *President*, SKF Industries, Inc.

The Unwritten Charter of Management

International Cooperation in Management, Th. Limperg, *Professor of Business Economics*, University of Amsterdam (Holland)

Friday, Sept. 23, 2:00 p.m.

Presiding: Lord Leverhulme

Social and Economic Aspects of Management, John G. Winant, *Director*, International Labor Office

Closing Remarks: Daniel C. Roper, Secretary of Commerce, U. S. A.

Technical Sessions

Papers dealing with subjects relating to administration, production, distribution, personnel, agriculture, and the home, will serve as the basis for discussion at the simultaneous technical sessions.

Heat Transfer Group Completes Preliminary Organization and States Objective

Broad Scope of Group's Interests Indicated

THE Heat Transfer Professional Group is the first Professional Group to be established by The American Society of Mechanical Engineers. A Group is a young Division; essentially, it differs from a Division only in age and size.

Prior to the Annual Meeting in 1937, the professional activities of the Society in the field of heat transfer were in charge of a subcommittee of the Process Industries Division, a status implying a scope of interest much less broad than is in fact the case. The generation and utilization of heat constitute one of the traditional basic fields of mechanical engineering, and the generation of heat and all its uses involve the flow of heat from one medium to another or from place to place within the same medium. Sometimes the problem lies in effecting directly useful heat exchanges; sometimes, in controlling losses. In many cases, problems yield to the same techniques of solution, whatever the field of industry in which they occur. Therefore, a consolidation of heat-transfer activities in a new Group, independent of any existing Division, and cooperating with all, has seemed advisable.

General Objective

The general objective of the Heat Transfer Professional Group is the improvement in design and operation of all types of heat-transfer apparatus. The broad scope of the Group's interests is indicated by the following general division of the field, which also serves as the basis for formation of technical committees as the development of the Group progresses:

(1) Principles of heat transfer and their applications; theory and analysis, experimental work for the elucidating of theory and methods of analysis, as distinguished from performance tests.

(2) Heated and cooled enclosures; heat transfer through walls of furnaces, buildings, insulation, losses from pipe lines, etc.

(3) Unfired equipment; heat exchangers, condensers of all kinds, unfired boilers and evaporators, air-conditioning equipment, etc.

(4) Direct-fired fluid heaters and boilers; steam boilers, tube stills, and cracking coils, superheaters, etc.

(5) Direct-fired solid heaters, melters, and smelters; ovens, glass lehrs, cement kilns, open-hearth furnaces, etc.

These classifications are deliberately designed to cut across the lines of industrial groupings, in the belief that the experience of one industrial group will be materially beneficial to another with related problems.

Preliminary Organization Completed

The details of preliminary organization of the Group have been completed, and its by-laws have been approved by the Standing Committee on Professional Divisions. The Executive Committee of the Group is proceeding with the formation of standing committees to promote its objectives. Continuous contact with individuals and groups conducting heat-transfer investigations and tests, or with those who have useful data available for publication, will be maintained by a Standing Committee on Coordination. This committee will have a considerable number of correspondents, widely distributed geographically. A second standing committee will critically examine available data on thermo-physical properties of substances which are important in heat-transfer calculations, and report the most acceptable values, subsequently revising these data annually as warranted by new determinations. This will aid in overcoming a major handicap to more general application of rational methods to heat-transfer calculations.

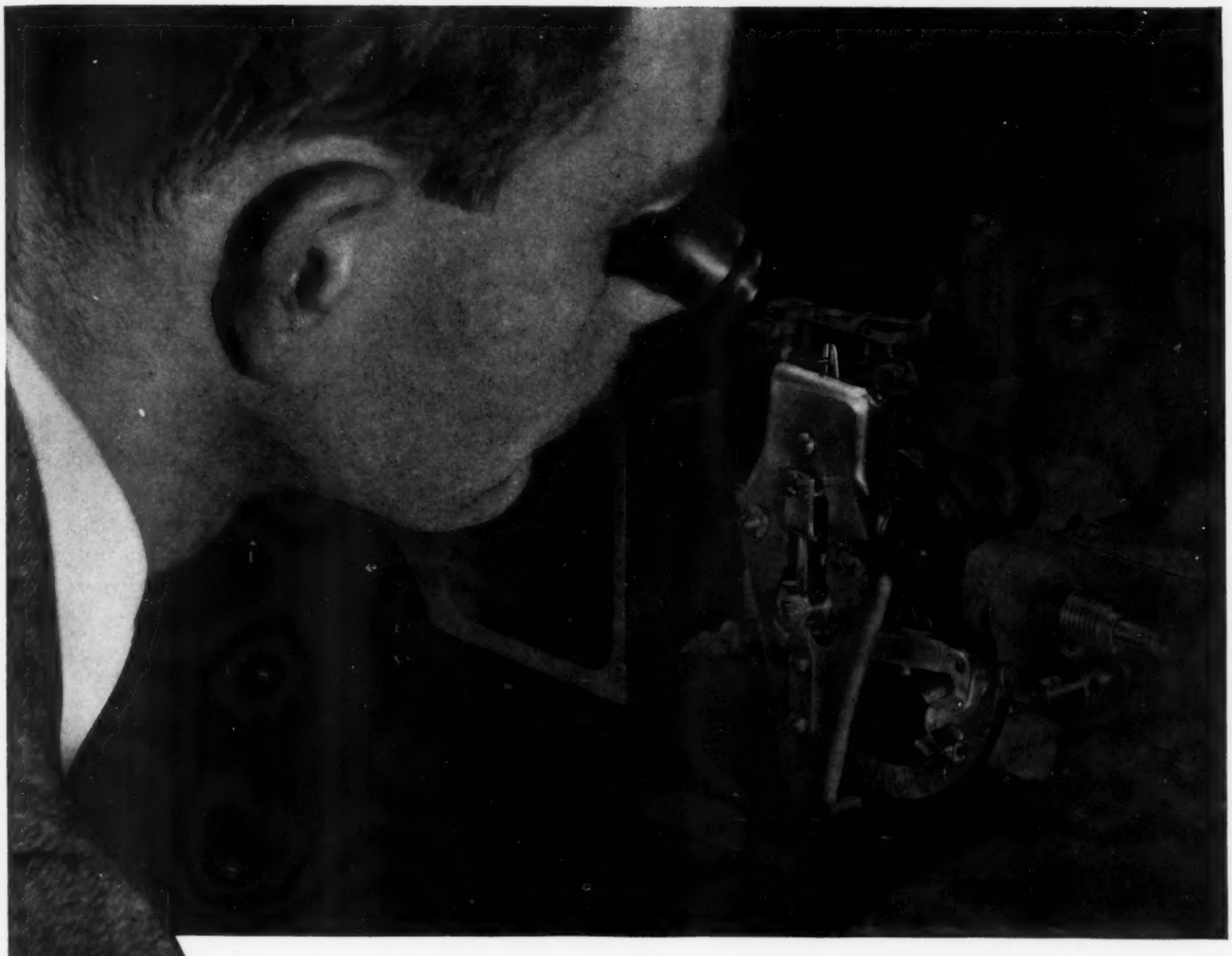
A third standing committee will report on acceptable techniques of testing heat-transfer equipment to secure data for analytical purposes as distinct from guarantee tests. It will include in its personnel, and consult with, experimental investigators of recognized ability and experience, in drawing up such codes. A fourth standing committee will carefully review and pass on papers and reports submitted to the Group, with aid of consulting experts.

Careful Selection of Committee Personnel

Satisfactory attainment of the Group's objectives will depend principally on the quality and activity of its working committees. Selection of personnel of the committees is accordingly being made with care, and with particular attention to variety of experience and viewpoints. It is the belief of the Executive Committee that many of the most valuable members of the working committees will be younger members of the Society who have not previously had opportunities for service on professional committees. The Executive Committee of the Group will welcome suggestions by anyone sufficiently interested to proffer them, of useful services to be undertaken, or of individuals who should be invited to participate actively in the work of the Group, as a committee member or individual contributor.

Correspondence concerning the Group should be addressed to either the chairman, Thos. B. Drew, E. I. du Pont de Nemours & Co., Wilmington, Del., or the secretary, E. D. Grimison, The Babcock & Wilcox Co., 19 Rector Street, New York.

(*A.S.M.E. News continued on page 722*)



TO WATCH THE *Tiny Changes* THAT MICROMAX CAN FEEL

If you were measuring temperature with a manual potentiometer, you'd try to keep your eye on the galvanometer pointer . . . where Micromax automatically keeps its feelers. You'd try to catch changes at the very start . . . as Micromax actually does.

But, to do a Micromax quality job, you'd need a magnifying glass to see the first minute motions of the pointer. For Micromax sees them while they are still too small for the naked eye . . . and before they would interest any pyrometer but Micromax, it moves indicator, recording pen and (in automatic control) the control valve, feeder or damper.

There is no clearance through which the galvanometer pointer has to move before its motion is acted on. The pointer merely "leans" against the feelers and the effect is as though it leaned directly against index, pen and valve . . . all at once.

)-N33(21)

See Catalog N-33A

LEEDS & NORTHRUP COMPANY, 4963 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

Junior Group Activities

Kansas City

TWO junior papers and a guest speaker featured the July meeting. Albert Will explained methods used in surveying metropolitan districts, and Max Brauninger discussed telephone maintenance problems. Mr. Westerman, of the General Electric Co., described the new steam turbine being installed at the Northeast Station of the Kansas City Power & Light Co. (The Junior Group inspected this plant in June.)

San Franciso

First meeting of the newly formed Junior Group was well and enthusiastically attended. Several Senior members present expressed approval and a desire to cooperate. The Group is making up a survey form to determine interest among potential members, and has found the Metropolitan Group's questionnaire helpful.

Tri-City

"Purification of Crude Oil and Manufacture of Gasoline" was the subject presented by Mr. Mull of the Wood River Refinery of the Shell Oil Co., at a recent meeting of the Tri-City Junior Group.

Metropolitan

The annual survey form was mailed about August 1, under direction of a committee headed by Sidney Davidson. Cooperation of the membership was anticipated so executive and administrative committees could move right ahead on plans for the coming year.

Cleveland

Final meeting of the year was held at Nela Park, "World's Lighting Headquarters." High lights included a demonstration of the new "fluorescent lumiline" lamp which resembles a mercury-arc lamp but which can, by use of chemical coatings inside, produce light in a number of pastel shades and a white shade close to daylight. The Group and its guests also saw demonstrations of an all-electric kitchen.

Philadelphia

Junior activities closed with a successful meeting addressed by O. E. Jansson on "Architectural Woodworking." The Group also inspected Richmond Station of the Philadelphia Electric Co.

Detroit

Officers for 1938–1939 season were elected at the final meeting: R. K. Weldy, chairman; O. F. Zahn and F. A. Jennings, members of executive committee. The second cooperative paper, "Air Conditioning" was presented by J. H. Stanek, who had the cooperation of S. A. Whitt, H. L. Boekleman, and J. P. Schecter in its preparation. Emphasis was on industrial air conditioning.

South Texas

"Educating the Engineer for Advancement" was discussed by Mr. Kenneth H. Condit, editor of *American Machinist*, at the June meeting. Mr. Condit's remarks were limited to presenting the work being done by the A.S.M.E. in promoting the education of both young and old engineers, and the possibilities of sponsoring lecture courses and symposiums. Lively discussion brought out the fact that South Texas Group meetings incorporated many of Mr. Condit's suggestions.

Portland

The Junior Engineer's Club of this Oregon city has, according to a report submitted by Dick F. Wagner, secretary, carried out a program similar to those of Junior Groups in other cities. A general meeting and inspection trip are held each month. Features of the program included a meeting on registration of engineers addressed by a member of the state board, a special program for high school students planning to study engineering, and an anniversary banquet. The club has three membership grades: Active, for graduates of approved schools of engineering or science; Associate, for graduates of high schools engaged in engineering work; and Honorary, for older engineers with an active interest in the Club.

Dr. E. L. Moreland Appointed Dean of Engineering

SUCCEEDING Dr. Vannevar Bush, member, A.S.M.E., who resigned to become president of the Carnegie Institution of Washington, Dr. Edward L. Moreland, member, A.S.M.E., who succeded Dr. Dugald C. Jackson, member, A.S.M.E., as head of the department of electrical engineering of M.I.T., has been appointed dean of engineering.

Conference on Engineering and Industrial Statistics

M.I.T. has announced a two-day conference on the application of statistical methods to industrial and engineering problems at Cambridge, Mass., Sept. 8–9, 1938. Further information may be obtained from the Secretary, Conference on Engineering and Industrial Statistics, M.I.T., Cambridge, Mass.

Men and Positions Available

Engineering Societies Employment Service

MEN AVAILABLE[1]

MECHANICAL ENGINEER, university graduate, age 36, three years as test engineer and on maintenance of boiler-room instruments; 2 years' power-plant construction; 16 months' layout, detailing power-plant piping. Me-131.

MOTION PICTURE ENGINEER, 25; single, M.E., now employed. Two years' experience in animation and motion-picture production; experience includes machine design, drafting, research. Associate S.M.P.E. No geographical preference. Me-132.

MECHANICAL ENGINEER, recent graduate. Two summers' experience as pipe-fitter's helper and draftsman in oil and asphalt refinery. Interested production or maintenance. Me-133.

MECHANICAL ENGINEER, recent graduate, B.S. degree from accredited engineering college. Speaks and writes English and Spanish. Training in welding, electrical and civil engineering. Advance work in drafting and mechanical shops. Me-134.

FUEL ENGINEER, age 32; Cornell '28, M.E.; M.I.T. '34. S.M. (Chem. Eng.). Service, design, and sales work with fuel-burning equipment. Desires connection power-plant field. Exceptionally well-rounded training. Me-135.

MECHANICAL ENGINEER, recent graduate 22, honor student, member Tau Beta Pi. Major subjects: Refrigeration, power-plant engineering, machine design. Experience in power-plant piping layout and drafting. Will travel anywhere. Me-136.

ENGINEER, 1938, graduate in mechanical engineering with thorough background in fluid dynamics and heat transfer, desires opportunity to use this training in field of design. Location Eastern U. S. Me-137.

MECHANICAL, STRUCTURAL ENGINEER. Sales organizer and manager. Previous position, chief engineer for 5 years. Has completed arrangements for financing company. Will be free about September to take another position. Correspondence invited. Me-138.

MECHANICAL ENGINEER, recent graduate. Young, good appearance. Interested design or production. Will travel anywhere. Me-139.

GRADUATE MECHANICAL ENGINEER, 30. Nine years' experience in design and maintenance of chemical plants and industrial power plants. Desires position with firm in chemical industry. Me-140.

TECHNICAL GRADUATE. Practical and theoretical experience in machine shop, steel mills, and by-product coke plant. Interested machine design, machine shop, maintenance, or construction. Location preferred, South. Me-141.

INDUSTRIAL ENGINEER, graduate, 29. Ex-

(*Continued on page 724*)

[1] All men listed hold some form of A.S.M.E. membership.

LUNKENHEIMER

Fig. 123 "N-M-D"

(NON-METALLIC DISC)

1 inch
Fig. 123
"N-M-D"

A serviceable bronze valve for steam; hot water; cold water, gas and air. The non-metallic disc (made in three basic types) is easily and quickly renewed.

Available in
Globe, Angle, Check
and Quick Operating
Patterns.

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8-18-4

perience in development and application of wage incentives, time and motion study, cost and production control, and labor relations. Interested primarily in supervisory or executive position. South preferred. Me-142.

ENGINEER, 19 years' experience in development, design, and sale of seamless tube mill and welded-pipe mill machinery. Expert on high production tube and bar cold-drawing machinery. Me-143.

MECHANICAL ENGINEER, recent graduate of Armour Institute of Technology; inventive ability, has made several inventions; desires permanent position with organization as development engineer. Will travel anywhere. Me-144-9594-Chicago.

POSITIONS AVAILABLE

MECHANICAL ENGINEER, about 30, single, to supervise general operation of oil stations. Must have wide acquaintanceship with various types of machines, and also actual construction experience along lines of warehouses, pipe lines, etc. Salary, $350 a month. Apply by letter. Location, South China. Y-3022.

ASSISTANT MANAGER, mechanical engineer, 35–50, with general executive engineering background and thorough knowledge of business procedure including sales, management, and engineering. Experience in power-transmission machinery desirable. Apply by letter. Location, New York, N. Y. Y-3174.

MECHANICAL OR CHEMICAL ENGINEER, 30–35, to act as writer for business and technical publications. Work will be in connection with uses of gases in industrial field. There will be traveling to collect information from which articles can be built up. Salary, $300 a month. Apply by letter. Location, N. Y. C. Y-3190.

FACTORY SUPERINTENDENT, 40–50, for airplane factory employing about four hundred men. Must have sheet-metal and machine-shop experience. Must also have experience making up shop schedules, estimating, etc. Salary, $5000 a year. Apply by letter. Location, East. Y-3198.

EMPLOYMENT MANAGER, 26–32, with several years' experience in employment office of manufacturing company. This experience is essential. Will also spend some time in cost-keeping department of company. Opportunity. Salary, $35–$40 a week. Apply by letter. Location, East. Y-3199.

ENGINEERING EXECUTIVE, 35–45, with thorough background in manufacturing for methods, operations, and cost reduction work for company operating number of plants. Must have good personality and have earned in excess of $5000 a year. Salary open. Location, East. Y-3201.

GRADUATE ENGINEER, 30–40, with experience in automotive traffic problems. Work will be with officials of towns and cities regarding installation of traffic markers, and supervision of such installations. Must have good personality. Apply by letter. Location, New York, N. Y. Y-3202.

SALES ENGINEER, about 35, with experience in sale and manufacture or uses of industrial ovens. Must be executive type, and able to organize department. There will be a great deal of traveling, organizing field representatives, etc. Apply by letter. Headquarters, Connecticut. Y-3207.

PRODUCTION MANAGER, 35–40. Mechanical or chemical engineer with poduction experience in printing inks or paint. While this experience is desired the company is also seeking man who can get along well in an organization, get results, and at the same time hold the esteem of the men. Salary, $5000 a year. Apply by letter. Location, N. Y. C. Y-3221.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after September 26, 1938, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references.

Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Reelection; Rt = Reinstatement; Rt & T = Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Member, Associate, or Junior

ANDERSON, ALEX., Midlothian, Scotland
BAITY, GEORGE W., Greensboro, N. C.
BAKULE, CARL V., Wyoming, Minn.
BOAZ, JOHN R., Burbank, Calif.
BOWMAN, CLARENCE BLISS, Oakland, Calif.
CAPOROSSI, ANGELO V., Lodi, N. J. (Re)
DOLL, ALFRED WILLIAM, Brooklyn, N. Y. (Rt & T)
ENGLER, W. G., Valley Stream, L. I., N. Y.
FARIDANY, H. P., Abadan, Iran
FISHER, HOMER V., Los Angeles, Calif.
GRAY, H. E., High Point, N. C.
HADLOW, H. RALPH, Cleveland, Ohio (Rt)
HARVEY, T. N., JR., Menlo Park, Calif.
HATTORI, T., New York, N. Y.
HEUSER, FRED, Gasport, N. Y.
HIGMAN, JAMES, Hollywood, Calif.
HOWARD, J. H., Houston, Tex.
JAIN, D. K., Lahore, India (Rt & T)
KARELITZ, M. B., Pasadena, Calif.
KEELER, LEONARD B., Detroit, Mich.
LINNEY, GEORGE E., Buffalo, N. Y.
LUNDQUIST, ELMER C., Buffalo, N. Y.
MARTIN, JOHN GREGORY, Cincinnati, Ohio
MELIN, H., Youngstown, Ohio
OTTERBACHER, ELLIOTT H., Chicago, Ill.
REID, JACK B., Carteret, N. J.
REID, JOSEPH G., Chicago, Ill.
SMITH, CHAS. G., Wash., D. C. (Rt)
SWEIGERT, R. L., Atlanta, Ga.

APPLICATIONS FOR CHANGE OF GRADING

Transfers to Fellow

BURTON, W. DEAN, Pasadena, Calif.
KOTHNY, GOTTDANK L., Strafford, Pa.

Transfers to Member

ERSKINE, JAMES H., Spencer, N. C.
MCCARTHY, JUSTIN J., Camden, N. J.
ROTH, PAUL V., Philadelphia, Pa.
SAYRE, RICHARD LER., Cincinnati, Ohio
YERZLEY, FELIX L., Wilmington, Del.

Necrology

THE deaths of the following members have recently been reported to the office of the Society:

ANDERSON, GEORGE F., June 23, 1938
BARNES, HAROLD B., May 12, 1938
BJORNSSON, CARL A., July 15, 1938
CAMPBELL, E. GORDON, June 23, 1938
COTHRAN, JAMES S., July 3, 1938
DAVIDSON, ARCHER, July 7, 1938
GILLIS, HARRY A., May 29, 1938
GOSS, EDWARD O., July 4, 1938
GREVE, EDGAR E., MARCH 6, 1938
JUNGHANS, EDWARD K., May 23, 1938
RICE, MYRON W., July 26, 1938
STRAUSS, JOSEPH B., May 16, 1938
THOMPSON, JOHN I., June 25, 1938
WILSON, ELLERY L., June 26, 1938

A.S.M.E. Transactions for August, 1938

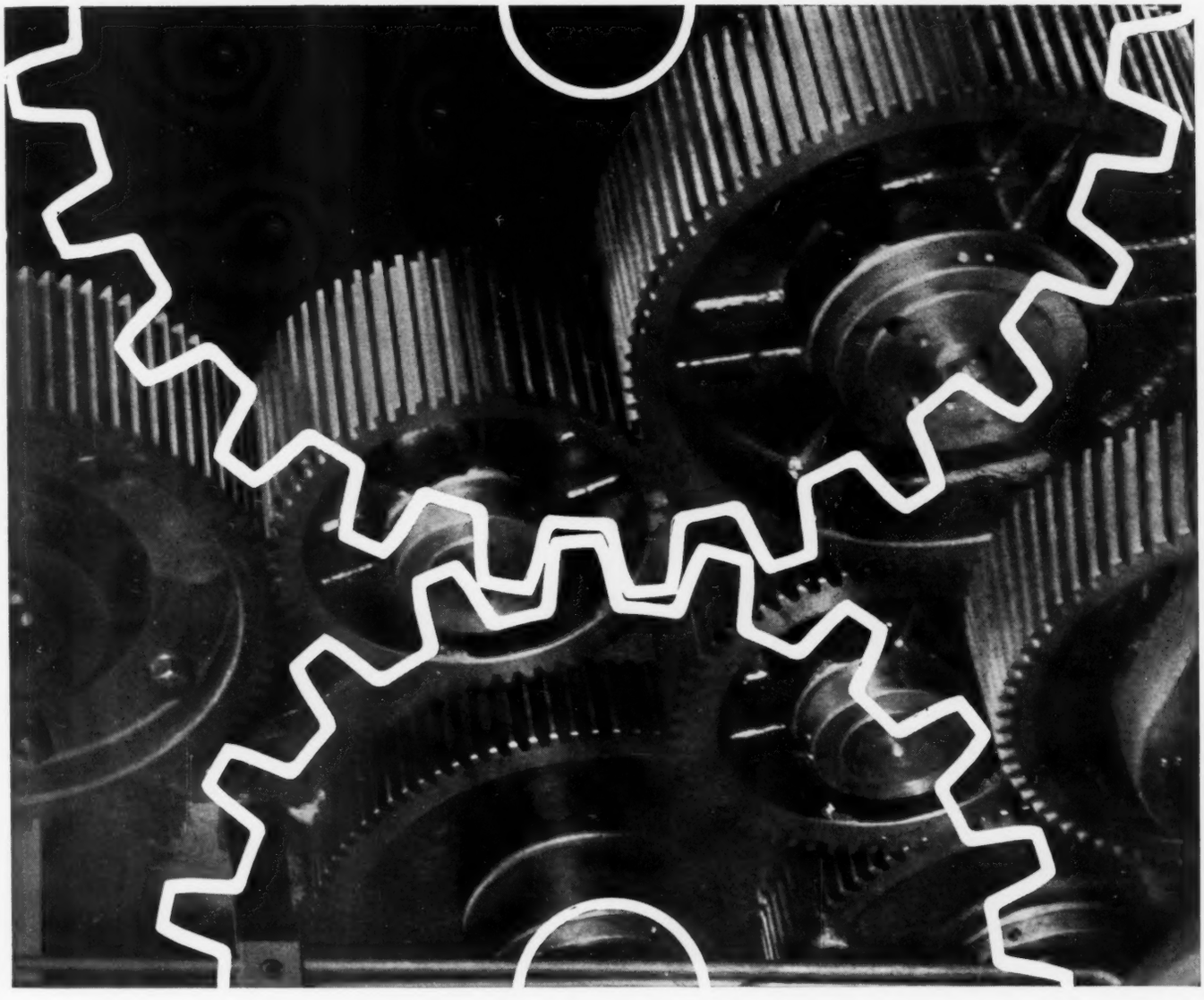
THE August, 1938, issue of the Transactions of the A.S.M.E. contains the following papers:

TECHNICAL PAPERS

- Combination Oil-and-Gas Burners (FSP-60-14), by O. F. Campbell
- The Behavior of Sodium Sulphite in High-Pressure Steam Boilers (FSP-60-15), by R. M. Hitchens and J. W. Purssell, Jr.
- Chlorination of Condenser Cooling Water (FSP-60-16), by R. B. Martin
- Design of High-Capacity Boilers (FSP-60-17), by John Van Brunt
- The Proportioning of Materials in Process Engineering (PRO-60-2), by J. C. Witt
- An Oil-Bath-Lubricated Railway Bearing (RR-60-3), by Albert Vigne and I. E. Cox

DISCUSSION

- On previously published papers by Messrs. G. H. Van Hengel; J. E. Angle and W. F. McGarrity; S. L. Kerr; J. M. Mousson; O. W. Boston, W. W. Gilbert, and K. B. Kaiser; C. L. Clark and R. S. Brown; C. E. Kraus and R. R. Weddell



PRECISION GEARS AT LOW COST

THE quality of the gears in a high-grade machine tool determines its performance.

One well-known machine-tool builder finds 0.35% Moly Chrome-Molybdenum iron meeting all requirements for main and intermediate gears in an automatic crankshaft lathe. The iron is wear-resistant enough to assure maintenance of original tooth profiles, thus eliminating tool chatter. Its structure—and therefore its strength—is uniform. There is no trouble from porosity at the bases of the gear teeth. This Chrome-Moly iron also holds down production costs. It is comparatively inexpensive. It machines easily. And in the case referred to above there has never been any waste from defective castings since it has been adopted.

If resistance to wear, uniform strength, plus economical production are vital requisites in the gears, pulleys or similar machine parts you make or use, investigate Moly irons. Our book, ***"Molybdenum in Cast Iron,"*** is free to engineers and production executives. Climax Molybdenum Company, 500 Fifth Avenue, New York City.

PRODUCERS OF FERRO-MOLYBDENUM, CALCIUM MOLYBDATE AND MOLYBDENUM TRIOXIDE

Climax Mo-lyb-den-um Company

MOLY

• Keep Informed . . .

Available literature may be secured by addressing a request to the Advertising Department of MECHANICAL ENGINEERING or by writing direct to the manufacturer and mentioning MECHANICAL ENGINEERING as the source.

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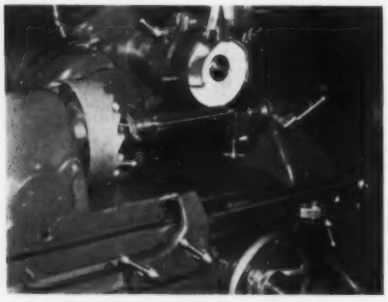
• *BUSINESS CHANGES*
• *LATEST CATALOGS*

Announcements from current advertisers in MECHANICAL ENGINEERING and the MECHANICAL CATALOG

• *NEW EQUIPMENT*

Combination Sharpening Machine



Barber-Colman Co., Rockford, Ill., announces a new product . . . the Combination Sharpening Machine for reamers, hobs and milling cutters. This new machine affords many advantages which have their origin in the Barber-Colman Automatic Hob Sharpening Machines and the Barber-Colman Reamer Sharpening Machine. However, the Combination Sharpening Machine does not replace these automatic machines, which are most suitable for economical large-volume production. It does not have their more costly specialized automatic features, consequently it makes available positive mechanical control of sharpening operations to a large number of shops which heretofore have been denied these advantages owing to insufficient volume of work. The advantages briefly outlined with many others are described in detail in a new circular just issued.

Portable Oxy-Acetylene Cutting Machine

The Linde Air Products Co., Unit of Union Carbide and Carbon Corp., 30 East 42nd Street, New York, N. Y., announces the Oxweld (Type CM-15) Portable Shape - Cutting Machine, the latest addition to its line of portable cutting machines. This new machine fills a definite place in the range of sizes from the smallest portable machine to the large stationary machines and does not displace any of the other Oxweld cutting machines now on the market.

The CM-15 combines many of the desirable features of both portable and stationary cutting machines. The machine weighs less than 200 lb. complete. All controls of the machine are conveniently located adjacent to one another. The cutting area—that is, the maximum range of blowpipe movement—is 60 in. lengthwise and 18 in. laterally. Cutting speed can be varied from 3½ to 28 in. per min., and a speedometer indicates movement directly in inches per minute. Accurate results can be obtained within the operating limits of the machine because of careful and precise construction.

Templet-tracing, hand-tracing, automatic circle-cutting, and straight-line cutting are all within the scope of operation of this machine. Any desired shape within the range of the machine can be automatically cut by the use of templets. A straight-line cutting guide is used for straight-line cutting in any direction. Circles from 2 in. to 18 in. in diameter are cut by the use of the circle-cutting attachment. Hand-tracing is accomplished by guiding the tracing wheel over a blueprint or drawing. Bevel-cutting up to an angle of 45 deg. can be done in either direction by merely shifting the angle of the blowpipe. In addition, a supplementary blowpipe bar, which is furnished with the machine, permits the use of two blowpipes for simultaneous cutting of similar shapes.

New Shakeproof Fastening Unit

SEMS—a pre-assembled Shakeproof Lock Washer and standard machine screw—is the latest addition to Shakeproof's broad line of metal fastening products. This new patented assembly unit saves time and money by reducing labor costs, speeding up production and eliminating such waste as lost lock washers. Also, SEMS offer a means for better product control because each screw is equipped with the correct size of lock washer for its particular type of head. And, as the lock washer cannot drop off, no screw can be applied without having a lock washer under the head. While designing engineers and production men have long realized the need for a pre-assembled lock washer and screw, it has been difficult to arrive at a method that would be practical and assure a definite saving to the user. Shakeproof has achieved this goal by the development of SEMS and preliminary tests in both large and small production plants indicate not only immediate cost savings, but faster and better production as well.

For literature describing SEMS in detail, write to Shakeproof Lock Washer Co., 2511 North Keeler Avenue, Chicago, Illinois.

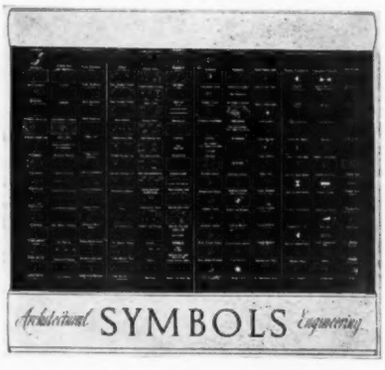
Toledo Speedweigh

A new scale has just been announced by the Toledo Scale Co., Toledo, Ohio. This "over-and-under" scale, or pre-determined weight scale, represents definite and obvious advances in design and in manufacture. This scale known as the "Speed-weigh" is designed by Harold Van Doren. It weighs 13 pounds as contrasted with the 50 of the prior model.

New Frederick Post Symbol Chart

No one who but at some time or other has been temporarily "stumped" in trying to locate the authentic drafting symbol for some form of construction. With dozens of different sources for various groups of hundreds of symbols, such a hunt is apt to take on the proportions of a major research before the needed symbol can be run to ground.

To eliminate this difficulty The Frederick Post Company, manufacturers of engineering and architectural instruments, equipment and supplies, has compiled on a single chart 249 symbols which were selected, with the cooperation of architectural and engineering societies and groups, from more than twice that number.



With professional help the Post Company was able to reproduce the "everyday" together with a great many of those hard-to-find symbols on a single chart 26″ × 35″ which they are now distributing *free* to Architects, Engineers and Users of Drafting Room supplies through their nation-wide network of Distributors.

A request to the Frederick Post Co., Chicago, or a telephone call to the nearest Post distributor will place the required number of charts in the hands of all requesters.

If Architects, Engineers and Draftsmen show interest in this technical cooperation, Post plans to make additional specialized charts available, feeling repaid for their undertaking through the opportunity of keeping the Post name associated with helpful data before the eyes of users of drafting materials.

Universal Straining Frame for Photo-Elastic Analysis

Photo-elastic analysis of structural models and models of machine parts has aroused a growing interest during the past few years, not only in university research laboratories but also in many industrial organizations. One of the primary elements in the optical train used for this method of analysis is a straining frame for loading models in a variety of different ways. Most laboratories have heretofore built their own straining frames and many of them have certain features in common.

A relatively low cost Universal type straining frame combining a number of desirable qualities is now being made available by the Polarizing Instrument Co. This frame will adapt itself to most of the loading conditions encountered in the analysis of structural models and in machine parts subject to two dimensional stress states. The straining unit consists of a rectangular frame which

Continued on Page 18

ADAPTABILITY

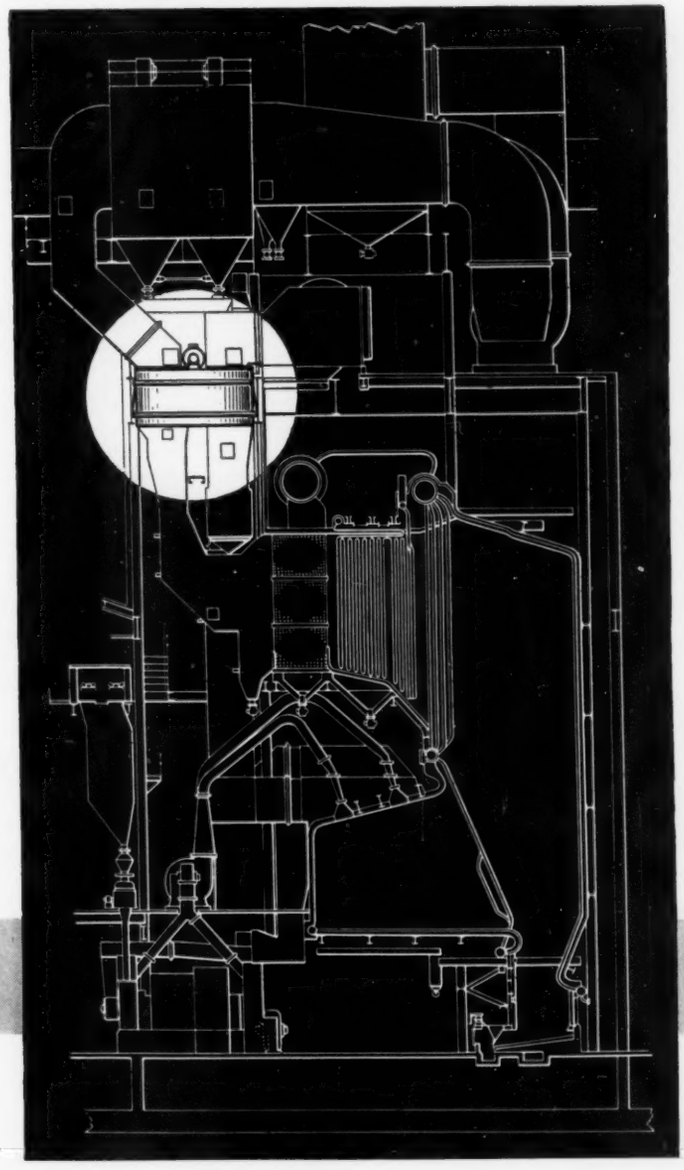
Ljungstrom Air Preheaters Have the Widest Range of Application

Each of the two high-capacity high-efficiency boilers at the Essex Generating Station of the Public Service Electric and Gas Company of New Jersey, is equipped with two Ljungstrom air preheaters. Air is preheated at maximum steam load to 550 deg. F. The gases are reduced to 337 deg. F.

Such high heat recovery is accomplished most economically with Ljungstrom air preheaters. The simplicity of design and compact arrangement, made possible by their use, are at once apparent from the illustration. In this instance, as well as many others, Ljungstrom air preheaters have been installed without adding to the space normally required for the boiler with its forced and induced draft fans.

Public Service Electric and Gas Co.

Essex Generating Station



THE AIR PREHEATER CORPORATION

Under the Management of THE SUPERHEATER CO.

60 East 42nd Street New York, N. Y.

Continued from page 16

slides vertically within an outer frame which slides horizontally on a steel base plate. As shown in the illustration, the specimen to be tested is mounted on supports fastened to the inner frame. By means of handwheels attached to the frames, the model may be moved either vertically or horizontally to any desired position so that the polarized rays will traverse the entire region for which the fringe patterns are to be studied.

The inside frame is made of double bars with a series of holes drilled along the vertical center line of the side bars. The lever arm, supported on pins inserted in these holes, slips in between the bars. It may be shifted vertically to any position, depending upon the type of specimen, by moving the fulcrum pin to the proper hole. The loading ratio is four to one, so that a one pound weight placed on the hanger at the end of the lever arm causes a four pound load on the model. The loading bar is made of aluminum alloy. A counterweight on one end of it will balance the weight of the bar, loading clevis, and hanger. Consequently, only the applied weights will actually cause loads upon the specimen.

The outside frame consists of vertical legs each made of two angles with space enough between them to permit the lever arm to slide freely. The top member, made of two bars rigidly connected at each end and a bottom thrust bar keep the frame in alignment and facilitate horizontal motion. Angle supports at the lower corners rest on the base plate and are kept in line with guide bars so arranged that the entire unit may be moved to any position on the supporting table. Moreover, the unit is heavy enough so that ordinarily specimens may be loaded without using clamps to fix the base plate to the supporting table.

The frame is adapted to bending, tension, or compression tests. A variety of small holders and supports may be designed and built to suit the needs of any user. The figure illustrates a small rigid frame bridge model with loading being applied to cause bending primarily. Note the loading clevis unit which is suspended freely from the lever arm. Loading contact is made by inserting small pins through holes and through rollers in the clevis unit. The rollers bear against the specimen. The rollers may be changed to give a variety of load points, such as a center loading, or a two-point loading symmetrical with respect to the center line, or an unsymmetrical loading. Other attachments are provided as standard accessories for both tension and compression.

Further details may be had by writing to the Polarizing Instrument Co., 8 West 40th St., New York, N. Y.

Vogt Meter Valves

The Henry Vogt Machine Co. of Louisville, Ky., announces a line of drop forged steel, union bonnet type, meter valves in one-quarter, three-eighths and one-half inch sizes.

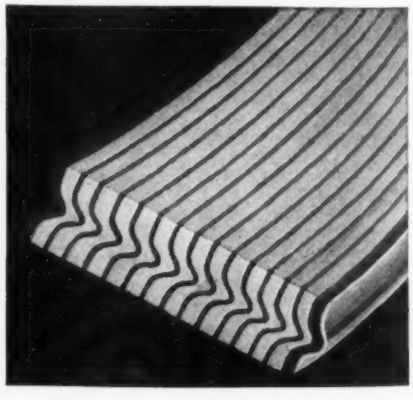
This type valve has numerous features, such as hexagon body ends, a ground joint between body and bonnet, a stem that can be easily reground or replaced and the valve may be repacked under pressure. Recommended for 900 lbs. W. P. at 750 deg. F. or 1500 lbs. non-shock cold working pressure and may be had of all-carbon or all-stainless steel to suit.

Vogt meter valves are especially suited for applications where close, dependable and safe regulation is important.

Johns-Manville New Spirotallic Gaskets

To meet service conditions on modern power plant equipment operating at high pressures, Johns-Manville, Inc., 22 East 40th St., New York, N. Y., has developed a new type of gasket constructed of preformed plies of asbestos and cold-rolled, cadmium-plated steel. Known as the "Spirotallic Gasket," it is for sealing boiler manholes, handholes and tube plates. The material is spirally wound in such a manner that the asbestos serves to seat the adjacent, interlocking metal plies. As soon as compression is encountered, the strong, rigid edges of the plies meet the bearing surfaces of the manhole, handhole or tube plate to form a series of metal barriers that provide a tight and effective seal against extreme pressures and high temperature conditions.

An outstanding feature of Spirotallic Gaskets is their ability to compress under flange pressure and then to rebound when the pressure is removed. This resiliency is



obtained largely by the central crimp of the interlocking plies, which provides a constant spring action that enables the gasket to compress and expand automatically as the gasketing space varies in service.

Tests conducted on these gaskets in the Johns-Manville Research Laboratories, and under actual operating conditions, have shown them to be both durable and efficient, with the result that the problem of follow-up is reduced and long service with low maintenance is assured. Often it is possible to use the same gasket over again.

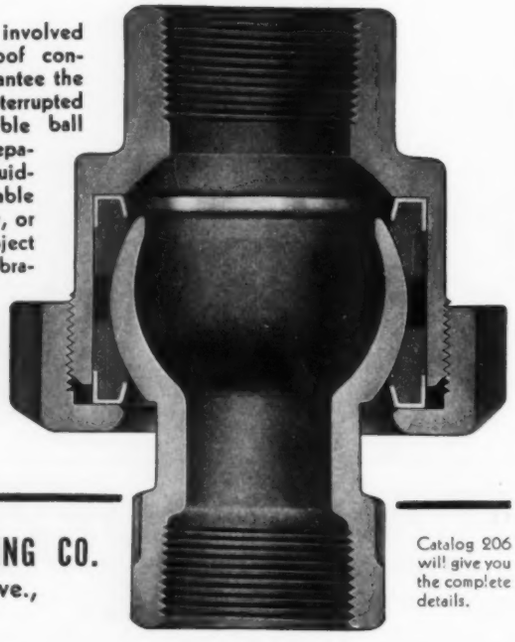
Spirotallic Manhole and Handhole Gaskets are available in standard sizes in both round and oval form. The sizes of Spirotallic Tube Plate Gaskets vary according to the boiler. This material is supplied in $\frac{1}{8}$,

Continued on Page 20

Complete Flexibility
Leakproof Service
Low Maintenance

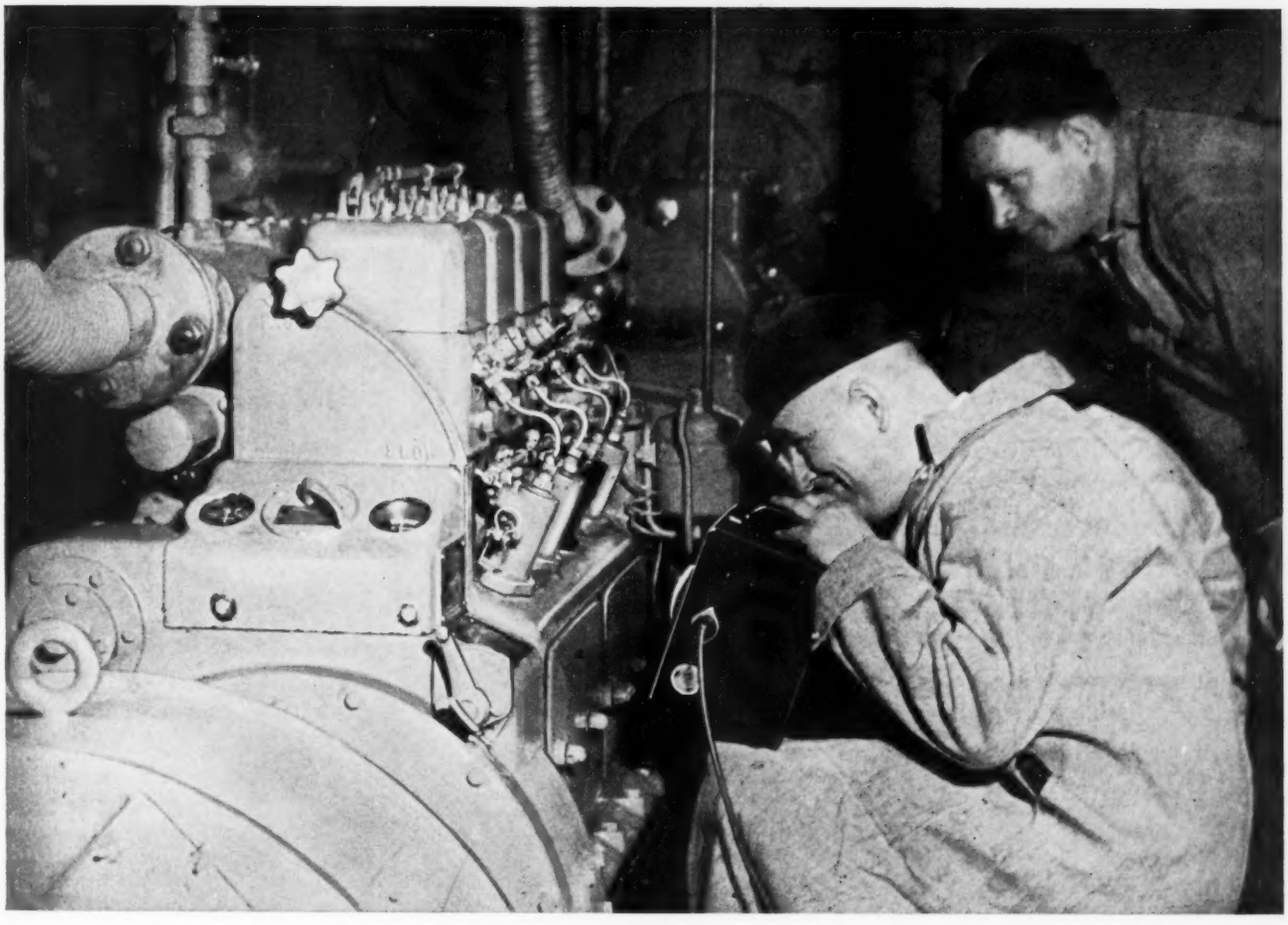
BARCO FLEXIBLE JOINTS

Wherever pipe movement is involved BARCO flexibility, leak-proof construction and longer life guarantee the savings and profits of uninterrupted production. BARCO flexible ball joints are provided with two separate and distinct non-metallic, fluid-tight seats, and are indispensable on any assembly of steam, air, or fluid-carrying pipe which is subject to movement, expansion, or vibration. Experienced engineers specify and use BARCO. Experienced operators always have them on hand in the storehouse.



BARCO MANUFACTURING CO.
1811 Winnemac Ave.,
Chicago, Ill.

Catalog 206 will give you the complete details.



For the Field Man

TYPICAL of the hundreds of applications of the STROBOTAC is the one illustrated, in which this simple-to-operate instrument is being used to study valve spring vibration . . . to determine why valve springs are breaking on this Diesel installation on a fishing trawler.

The STROBOTAC is a service man's tool just as much as it's a research instrument for the design engineer, for it STOPS MOTION for both. Extremely simple to operate, portable, light-weight, inexpensive, the STROBOTAC can be used to analyze *any* reciprocating or rotating cyclic motion between 600 and *72,000 rpm.* It is calibrated directly in rpm to an accuracy of 2% from 600 to 14,400 rpm.

The STROBOTAC is being used daily in the Diesel field to observe and measure crankshaft whip, action of valve springs and connecting rods, backlash and wear in gears, loose camshaft bearings, loose and worn valve stems and other faults.

The STROBOTAC complete and ready for immediate operation costs only $95.00. It can help you in your motion studies. Let us show you how.

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GENERAL RADIO COMPANY

Cambridge, Massachusetts

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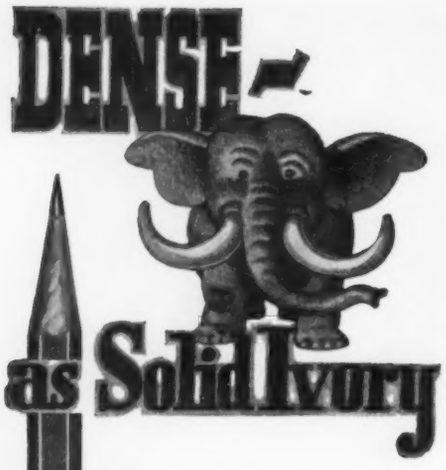

DENSITY in a drawing pencil usually means fine lead. In Mars Lumograph it means that and more—it means *opacity*—the resistance to light which now enables you to get

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You make direct reproductions because you want to save time, work, money—but you do not want to sacrifice quality. Nor do you need to—Mars LUMOGRAPH reproductions will give you greater clearness, sharpness, beauty of line than you have ever experienced.

The reason is that Mars Lumograph's fine lead has a special light absorbing element added to it.

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You will also find Lumograph superior for all your drawing. It is most accurately graded, it is absolutely gritless, it is perfectly uniform—every lead in every pencil and every pencil in every box is the same all the way through. It is beautifully finished, with the degree marked on all six sides of the tip. 17 degrees—15c each—$1.50 the dozen in a metal box. Ask your dealer or send us your order and his name.

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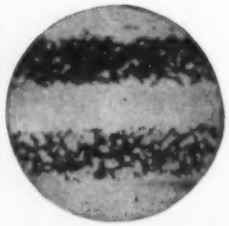


Photomicrograph of Lumograph line (upper), and other drawing pencil (lower); Proving Lumograph's superior opacity.

MARS LUMOGRAPH

• Keep Informed . . .

Continued from page 18

3/16 and 1/4-inch thicknesses. Special shapes of Spirotallic Gaskets which are not standard can be manufactured on short notice.

• BUSINESS CHANGES

Addition to Norma-Hoffmann Factory

The Norma-Hoffmann Bearings Corp., Stamford, Conn., due to an increasing demand for its ball, roller and thrust bearings, has just completed an extension to its present buildings and has placed substantial orders for new machine tool equipment.

"Timken Graphitic" Distributors

To provide more complete distribution for "Timken Graphitic" steels for dies and tools, the Steel and Tube Division of The Timken Roller Bearing Company announces the appointment of A. Milne and Co. 745 Washington Street, New York City, 109 Broad Street, Boston, Mass. and 21 North May Street, Chicago. This company will cover the six New England states, New York metropolitan district, eastern New York state and northern New Jersey. The Chicago office will cover the states of Illinois, Iowa, Missouri, Wisconsin, Minnesota and northern Indiana.

The Hamilton Steel Company, E. 131st and Taft Avenue, Cleveland, Ohio, to cover the state of Ohio, excepting the Dayton district and the city of Toledo.

The Craine-Schrage Steel Company, Detroit, Michigan to supply the state of Michigan and Toledo, Ohio.

Quality Steels, Inc., Dayton, Ohio to cover the Dayton district.

Coulter-Sibbett Steel Co., 240 Eighth Street, Oakland, Calif. to handle all accounts in northern California.

"Timken Graphitic" steels combine the uniformity of structure, freedom from segregation and porosity, response to heat treatment and physical properties of fine steel with the free machining qualities, resistance to wear and good frictional properties of cast iron. The steels are marketed by The Timken Roller Bearing Company, Steel and Tube Division, Canton, Ohio, and by the distributors just announced.

56,411 Visit Schenectady G-E Works

During the first six months of the current year 56,411 persons visited the Schenectady plant of the General Electric Company. The visitors represented practically every section of the United States, as well as many well-known and some seldom-heard-of cities in far corners of the earth.

Because of the thousands of tourists passing through the city during the summer months, the number of visitors to the Schenectady plant during the vacation period is usually double that of the rest of the year. The months of July and August bring the most persons to the plant, according to F. H. Field, veteran G-E receptionist. Four guided tours through the works are conducted daily, Mondays through Fridays.

Link-Belt Promotes Bond and Dyson

Link-Belt Company, Indianapolis, Indiana, announces that William W. Bond has been appointed western sales manager of the positive drive division, with headquarters at the Dodge plant in Indianapolis, to succeed G. Howard Burkholder, deceased. Mr. Bond has been in the company's employ since 1911, first serving in the engineering department at the Philadelphia plant. For the last 15 years he has been engaged in the sale of roller chain drives.

Coincidentally with Mr. Bond's promot on Ralph S. Dyson, for many years manager of stock silent and roller chain drive sales through distributors, will also head up roller chain sales to duplicate machinery manufacturers. Mr. Dyson entered the company's employ in 1899.

• LATEST CATALOGS

New Time Study Instrument Catalog

A. R. & J. E. Meylan, 268–70 West 40th Street, New York, N. Y., have just issued a new 12-page catalog showing some 40 types of Stop Watches, Timing Instruments, Stop Watch Stands, Time Study Boards, etc. Included are two new timing instruments—an Electric Stop Clock and an Interval Timer with Alarm. Each instrument is illustrated and fully described in detail.

"Checking Up on Check Valves"

"Checking Up on Check Valves," an eight-page, two-color booklet just issued by Crane Co., 836 South Michigan Avenue, Chicago, Ill., covers the whole check valve field in word, picture and diagram. The two basic types of check valves are described, their various applications are discussed, ten "Do's and Don'ts" are listed and two entire pages are devoted to cross-section views in what is called a "Handy Reference Guide to Crane Check Valves." The booklet is virtually a textbook on the subject.

Monel Metal in Steam Specialties

"The Third Essential in Steam Specialties" is the title of a booklet just issued by The International Nickel Co., 67 Wall Street, New York, N. Y. This booklet outlines a practical method for judging how well steam specialty equipment is made to give long service without repairs. Explains which parts are the vital parts, and which materials are especially suitable to make vital parts for different types of service. Illustrated with twenty-two actual examples.

Socket Screws

A new publication on Bristo Socket Set and Cap Screws has been recently published by The Bristol Co., 21 Bridge Street, Waterbury, Conn. This new bulletin gives prices and briefly describes the principle involved in the MULTIPLE-SPLINE design of these socket screws, that gives added strength to all sizes—as small as No. 4 and as large as 1 in. diameter. A copy of Bulletin No. 836 may be obtained upon request.

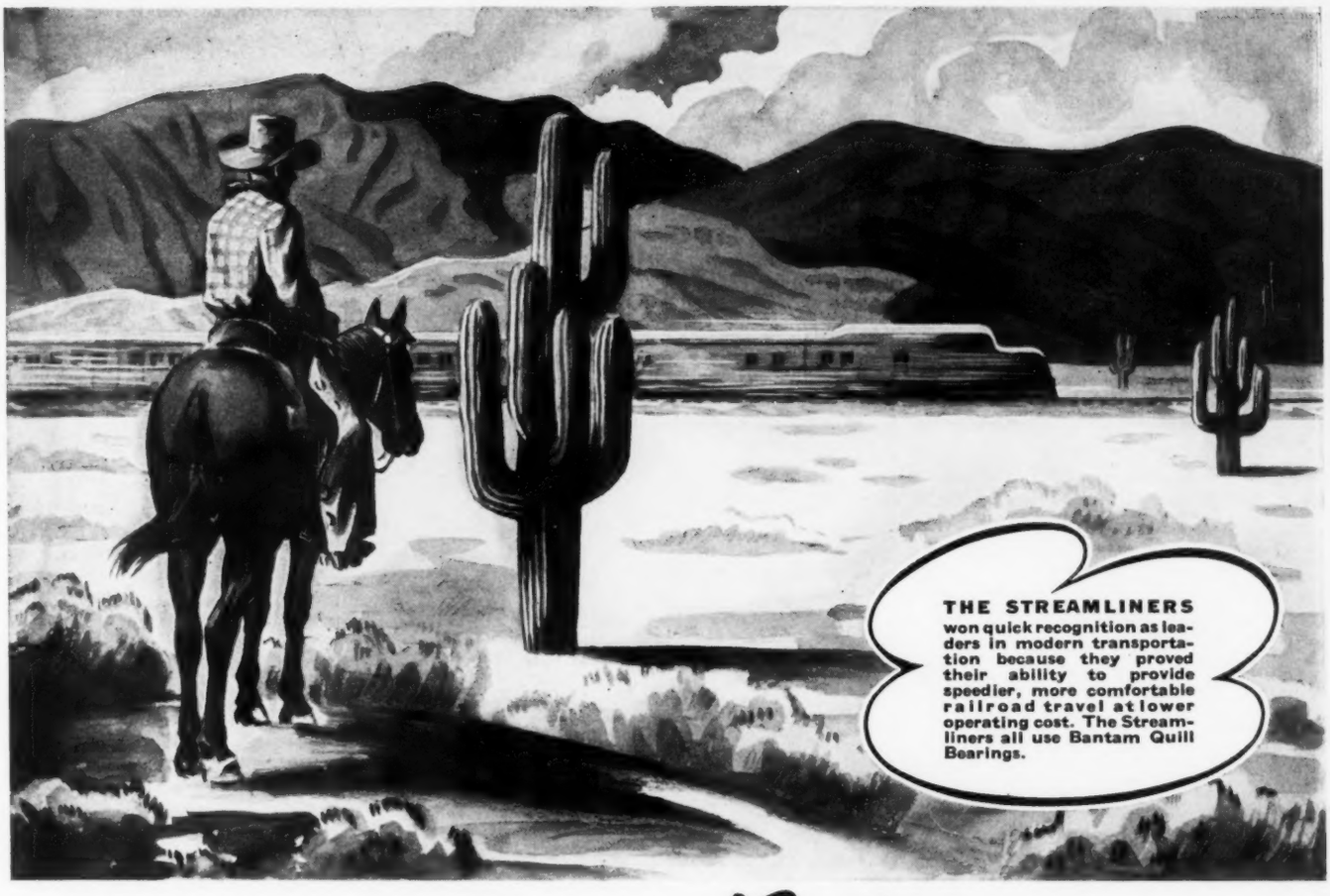
Lunkenheimer List Price Schedule R1

The Lunkenheimer Co., P. O. Box 360, Annex Station, Cincinnati, Ohio, has recently issued a new 44-page List Price Schedule which supersedes all previously published list prices. It covers the entire line of Valves, Boiler Mountings, Lubricating Devices which are listed numerically by figure number. These Schedules are available through Lunkenheimer Distributors in all industrial centers and from the Company direct.

New Link-Belt Coal, Ashes Handling Catalog

Solving the Problem of Coal and Ashes Handling in the Power Plant, is the title of a new Book No. 1510, of 32 pages, copiously illustrated, containing ideas and suggestions

Continued on Page 22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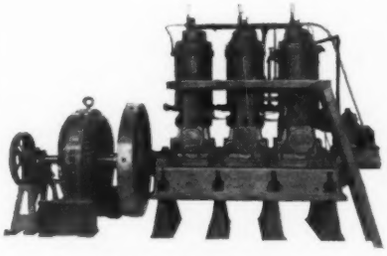

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USES BANTAM QUILL ROLLERS

The quality and design that have made Bantam Quill Roller Bearings standard equipment on the streamlined trains throughout the nation are also preferred for use on Ball-Muncie Diesel Engines. Shown above is one of their 165 h. p. Diesel Engines using Bantam Wrist Pin Bearings.

WE ask you to judge BANTAM BEARINGS not by what we *say* but by what they *do*.

The nation-wide recognition which Bantam has won in important industrial fields is based on records of performance which speak for themselves.

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RATE Announcements under this heading in MECHANICAL ENGINEERING are inserted at the flat rate of $1.25 a line per issue, $1.00 a line to A.S.M.E. members. Minimum charge, three line basis. Uniform style set-up. Copy must be in hand not later than the 10th of the month preceding date of publication.

• Keep Informed . . .

Continued from page 20

for cutting handling costs in the power plant by means of elevating and conveying equipment, coal crushers, etc.

It is pointed out that the question is not, "Shall I install handling equipment?" but, "What handling equipment best suits my requirements?" The many illustrations show how a great variety of handling conditions were met, particularly in boiler plants of moderate size.

A copy of this book No. 1510 will be sent to any interested reader upon request, which may be addressed to Link-Belt Company at 300 W. Pershing Road, Chicago, or 2045 W. Hunting Park Ave., Philadelphia, or to the nearest office of the company.

Grey Iron Specifications

If you are a user of cast iron, even to a limited degree, you should profit by a study of A Guide to Engineering Specifications for Grey Cast Iron, which is issued by The International Nickel Co., 67 Wall Street, New York, N. Y. The proven compositions have helped to elevate cast iron to a prominent position in the list of reliable engineering materials.

Higher strength, improved machinability, better resistance to wear as well as other valuable properties are available today at a very nominal premium. Because of their better performance and longer useful service life the slight premium which they bear may be translated into an attractive ultimate economy.

Tables I, II and III of this guide are comprehensive in scope yet they conveniently present reliable data for the busy engineer and purchasing agent interested in improved grey iron castings.

Copies of this data sheet have been sent to all listed grey iron foundries, hence, instructions or inquiries based upon the compositions shown will be understood and accepted by your source of supply.

Valve Reference Book

The new Homestead Valve Reference Book No. 38 is just off the press. This book features a more complete line of boiler blow-off valves; several new lines of Lift-Plug Valves; more complete dimensions, tables, and facts about Homestead Valves; a new line of Semi-Steel 500 pound O. W. G. (oil, water, gas) valve for the Oil Industry; and prices which are generally lower.

In addition, there are three full pages of suggested uses for valves in all industries, and suggested metals for special service conditions which users find very helpful in solving valve problems. A copy of this book may be had from Homestead Valve Manufacturing Co., P.O., Box 82, Coraopolis, Pa.

Impact Reaction Steam Turbine Units

Allis-Chalmers Mfg. Company, Milwaukee, Wisconsin, Steam Turbine Division, has come out with a new bulletin 1191 which covers one frame size of a complete line of impulse reaction steam turbine generating units. These turbines contain most of the design features used so successfully in large 3600 rpm turbines. The frame size illustrated and described by this bulletin has been designed for a capacity range of 1000 to 1500 kw.

Magnetic Separators

Magnetic Separators for removing tramp iron is the subject of a new eight-page folder recently issued by Stearns Magnetic Mfg. Co., 614 S. 28th St., Milwaukee, Wisconsin, describing Stearns Magnetic Separators of the spout type. Featured are the Stearns Class "A" Automatic Spout Type Magnetic Separators for use on hammer mills and similar grinding equipment; the Stearns High Duty Giant Safety Spout Magnet equipped with automatic gate and designed especially for lump and coarse material operation; the Stearns Type "LS" and "LP" Spout Separators made particularly for dust-tight operations; and the Stearns High Duty Magnetic Pulley Separator units.

Metal Cutting Tools

"Haynes Stellite-2400 Metal Cutting Tools," an illustrated folder describing the new high-production metal cutting alloy, Haynes Stellite-2400, has just been published by Haynes Stellite Company, a Unit of Union Carbide and Carbon Corporation. Available sizes and styles of standard Haynes Stellite-2400 square and rectangular tool bits and welded tip tools are given, together with the prices and a brief description of how the tools are best employed and what materials they will machine economically. This booklet also contains a complete list of grinding wheels for sharpening tools of this alloy, general recommendations on grinding practice and wheel speeds, and numerous illustrations showing typical machining operations on which the alloy is being used. Copies of this folder can be obtained from Haynes Stellite Company, Kokomo, Indiana.

COMING MEETINGS AND EXPOSITIONS

For the next three months

SEPTEMBER

3–5	National Aeronautical Association, 16th National Air Races, Cleveland, Ohio.
5–9	American Chemical Society, Fall Meeting, Milwaukee, Wis.
15–17	American Foundrymen's Association, Second Fall Technical Conference, Michigan Union Bldg., Ann Arbor, Mich.
15–18	Steel Founders Society of America, Fall Meeting, White Sulphur Springs.
27–30	Association of Iron & Steel Engineers, Annual Convention and Iron and Steel Exposition, Cleveland, Ohio.

OCTOBER

5–7	The American Society of Mechanical Engineers, Fall Meeting, Providence, R. I.
10–12	American Gear Manufacturers Association, 21st Semi-Annual Meeting, Skytop, Pa.
10–14	National Safety Council, Silver Jubilee Congress, Stevens Hotel, Chicago, Ill.
Wk. of 10th	American Gas Association, Annual Convention, Atlantic City, N. J.
12–14	American Society of Civil Engineers, Fall Meeting, Rochester, N. Y.
14–16	Second International Aerobatic Competition and St. Louis Air Races, St. Louis, Mo.
16–21	American Welding Society, Annual Meeting, Detroit, Mich.
Wk. of 17th	American Society for Metals, Annual National Metal Congress, Detroit, Mich.

NOVEMBER

9–11	American Institute of Chemical Engineers, Philadelphia, Pa.
14	Society of Automotive Engineers, Annual Dinner, Commodore Hotel, New York, N. Y.
14–18	American Petroleum Institute, 19th Annual Meeting, Stevens Hotel, Chicago, Ill.
17–19	National Machine Tool Builders' Association, Fall Meeting, Hotel Homestead, Hot Springs, Virginia.